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The ITRC is a global initiative dedicated to bringing temperate rice growing countries together for the discussion, promotion and advancement of research, technology and innovation in the field. This initiative enables information exchange among leading scientists and other stakeholders engaged in the sustainable intensification of rice production in temperate zones of the globe.

Previous editions of the International Temperate Rice Conference were held in Australia (1994), United States (2000), Uruguay (2003), Italy (2007), Spain (2014) and Australia (2017), with advancements and contributions to research groups around the world on novel rice breeding and management techniques, focused on temperate environments.

Embrapa - Clima Temperado Office, warmly thanks all participants that joined us at the 7th International Temperate Rice Conference (7th ITRC), held in Pelotas, Rio Grande do Sul, Brazil, in February 09th-12th 2020, and the Organizing Committee wishes that the participants have enjoyed and were enriched by the contents presented in panels, plenary and poster sessions, as well as the visits to the Quatro Irmãos Farm and to the 30th Rice Harvest Opening Fair.

André Andres
General Chairperson
Embrapa Clima Temperado
Pelotas, Brazil - February 2020

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by the Organizing Committee, or the respective paper was presented in oral form.

SUMMARY

❶ *Abiotic stress*

Interaction between salinity and ALS-inhibitor resistance and consequences on germination and seedling growth in rice, weedy rice and barnyardgrass

S Fogliatto, F De Palo, M Milan, L Patrucco and F Vidotto
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ABSTRACT

Water and soil salinization are among the most important abiotic stresses affecting many rice cultivation areas worldwide. Weeds are the principal biotic constrain to rice production and the occurrence of herbicide resistant populations has made more difficult their control. The study aimed at evaluating the effect of salinity on seed germination and seedling growth of rice and some barnyardgrass (*Echinochloa* spp.) and weedy rice populations (*Oryza sativa*), collected in Italian rice fields, resistant and sensitive to ALS-inhibitor herbicides. Seed germination tests were conducted in Petri dishes under nine different salt concentrations from 0 to 400 mM NaCl. Effect of salinity on emergence and seedling growth of weeds and rice were evaluated in greenhouse by growing plants in alveolar trays with a saline solution at concentrations ranging from 0 and 250 mM. The effect on weeds of the possible interaction between salinity and herbicide treatment (with penoxsulam and imazamox applied at field rate) was also tested. Germination and plant growth of herbicide resistant rice and weeds were generally more affected by salinity as resistant weedy rice and the resistant variety CL80 showed 98% and 96% germination reduction, respectively. The species less affected by salt was the sensitive rice variety Baldo that only showed a 57% of germination reduction. Barnyardgrass growth was generally less affected by salt presence than the other species, while weedy rice and rice were devitalized at salt concentration of about 100 mM. When weedy rice was treated with imazamox, only few growth parameters were affected by salinity, such as plant height and chlorophyll content. Link between salinity response and herbicide resistance was not observed for all species and growth parameters; however, weeds tolerant to salt, i.e. barnyardgrass, also characterized by herbicide resistance, can be more problematic in saline rice areas.

Key words: salt, red rice, ALS-inhibitor herbicides, herbicide resistance.

Interaction between salinity and ALS-inhibitor resistance and consequences on germination and seedling growth in rice, weedy rice and barnyardgrass

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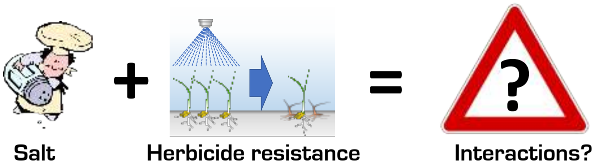
Introduction

Salinization and weeds are the most important abiotic and biotic constrains affecting rice cultivation worldwide.

Moreover, herbicide resistance is a further threat to rice cultivation.

Objective

- Evaluating the effect of salinity on seed germination and seedling growth of rice, weedy rice (*Oryza sativa*), and barnyardgrass (*Echinochloa crus-galli*) populations.
- Finding possible interactions between salinity and herbicide resistance.



Material and Methods

Populations

- Rice: 1 conventional (Baldo) and 1 CL (CL80) cultivar.
- Weedy rice: 4 sensitive (ws1, ws2, ws3, ws4) and 1 resistant (wr1) to imazamox.
- Barnyardgrass: 3 sensitive (bs1, bs2, bs3) and 3 resistant (br1, br2, br3) to ALS-inhibitors (target site resistance).

Trials

Laboratory trial

- Petri dishes with 20 seeds of each population/cultivar were prepared with 5 ml of saline solution (9 different concentrations).
- Incubation at 25 °C for 15 days.

assessments: germinated seeds (daily)

Greenhouse trial

- Emergence and seedling growth in alveolar trays floating on different saline concentrations.
- Seedlings treated at BBCH 12-13 with imazamox (weedy rice, CL80) or penoxsulam (barnyardgrass) at field rate.

assessments: seedling biomass at 21 days after treatment.

Trial	Tested NaCl concentration (mM)
Laboratory	0 – 50 – 100 – 150 – 200 – 250 – 300 – 350 – 400
Greenhouse	0 – 50 – 100 – 150 – 200 – 250

Data analyses

- Regression analysis between salt concentrations and germination.
- Estimation of salt concentration required to reduce by 50% seed germination (EC_{50}).
- Evaluation of the interaction between salinity and herbicide treatment.

Results

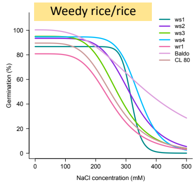
Laboratory trial: seed germination

Weedy rice and rice

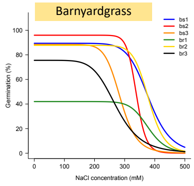
- Total germination affected by salinity, in particular at [NaCl]>200 mM.
- Imazamox-resistant weedy rice and CL80 showed the highest sensitivity to salinity (lowest EC_{50}) among weedy rice populations and rice cultivars.
- Good tolerance to salinity in conventional Baldo cultivar.

Barnyardgrass

- Poor germination (<50%) in one ALS-inhibitor resistant barnyardgrass population (br1).
- In general, higher tolerance than weedy rice and rice.



EC_{50} Weedy rice - Rice	
ws1	312.8 *c*
ws2	310.3 *bc*
ws3	270.1 *ab*
ws4	338.3 *cd*
wr1	229.6 *a*
Baldo	369.6 *d*
CL80	247.2 *a*



EC_{50} Barnyardgrass	
br1	-
br2	372.5 *d*
br3	246.3 *a*
bs1	371.3 *d*
bs2	337.5 *c*
bs3	279.2 *b*

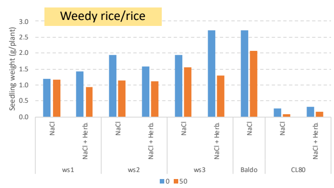
Greenhouse trial: seedling development

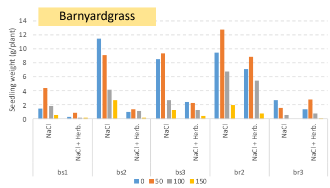
Weedy rice and rice

- More affected by salinity than barnyardgrass.
- From 100 mM NaCl: germination occurred, but seedlings growth was inhibited.

Barnyardgrass

- From 200 mM NaCl: germination occurred, but seedlings growth was inhibited.
- Growth stimulation observed at 50 mM NaCl in some populations.





Conclusions

Germination and seedling growth was affected by salinity both in rice, weedy rice and barnyardgrass.

Barnyardgrass germination and seedling growth was generally less affected by salt.

Germination of imazamox resistant weedy rice was more affected by salinity than that of sensititive populations.

Seedling growth under saline conditions seems to be unrelated to herbicide sensitivity/resistance.

As consequence of climate change, barnyardgrass is expected to become an even more serious threat to rice cultivation in areas where salinity is predicted to increase.

Understanding low temperature tolerance at the young microspore stage under aerobic conditions in rice.

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ABSTRACT

Non-flooded aerobic rice production is proposed in temperate Australia to improve water productivity. However, there is limited understanding for aerobic production in a temperate environment and its effects on low temperature tolerance at the young microspore stage (YMS). To further our understanding of low temperature tolerance under aerobic conditions, a series of experiments were conducted under controlled temperature flooded and aerobic conditions, as well as aerobic field cold screens to evaluate spikelet sterility and floral traits. The genetic material evaluated included fixed genotypes (17), and 52 F6:7 M205/3/M205/Millin/Lijianghiegu (2MML) genotypes, in which Lijianghiegu was the low-temperature tolerance donor.

Strong positive correlations existed between spikelet fertility obtained under flooded and aerobic conditions in 17 genotypes (r_p=0.73**) and 2MML genotypes (r_p=0.84**; r_g=0.91) after exposure to cold temperatures (15/21.5°C) at YMS. Furthermore, strong genetic correlations existed for spikelet fertility between the glasshouse and the aerobic field screening (r_g=0.49-0.63). The broad-sense heritability was higher in the glasshouse (0.87-0.96 vs 0.53), demonstrating that selection in the glasshouse is more repeatable.

In two flooded glasshouse experiments, the number of dehisced anthers (NDA) and pollen on stigma explained more phenotypic variation for spikelet fertility than the two aerobic experiments. In the 2MML lines, the lower phenotypic correlation between the NDA and spikelet fertility in aerobic (0.65**) compared to flooded (0.83**) was attributed to a lower environmental covariance as opposed to the genetic covariance which remained high for the floral traits quantified (r_g=0.94-0.98). The number of germinated pollen grains on the stigma (GPOS) explained the most phenotypic variation (75%) in spikelet fertility under aerobic as a result of a lower environmental variance. The results suggest that the underlying floral mechanisms for cold tolerance are similar under flooded and aerobic conditions, and that GPOS is a more reliable measure of YMS cold tolerance compared to other floral traits.

Key words: aerobic rice, young microspore stage, low temperatures.

Off-Target Florpyrauxifen-benzyl and its Effect on Soybean Yield Components

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ABSTRACT

In the Southern United States, there are many areas where rice (*Oryza sativa* L.) and soybean [*Glycine max* (L.) Merr.] are grown near one another. Many of the herbicides used in rice or soybean are only labeled for one crop and can be injurious to other crops. Due to this, there are many instances where herbicide applications move off-target and deposit on susceptible vegetation. Florpyrauxifen-benzyl is a new synthetic auxin that has activity on select broadleaf, grass, sedge, and aquatic weeds in rice. Soybean have shown to be extremely susceptible to off-target florpyrauxifen deposition, like other synthetic auxin herbicides. Therefore, a study was conducted to determine at what application timing and what rates this herbicide can damage soybean and the impact it has on soybean yield components. Treatments were arranged in a 2-factor factorial, with factor A consisting of application timing at either the V4 to V5 or R1 to R2 growth stage and factor B consisting of a 5-rate titration from 1/4 to 1/1028 of a florpyrauxifen rate of 29.44 g ai ha^{-1}. A rate of dicamba shown to cause minimal injury and with little to no yield loss was also applied as a comparison. Herbicide applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} of spray solution. Injury ratings and plant height were recorded at 1, 7, 14, and 28 DAT. Results indicated that all applied rates of florpyrauxifen resulted in total plant death at the 1/4 rate to a 12% yield reduction at the 1/1024 rate. Furthermore, there was no difference between application timings with regards to soybean yield. Yield components were also affected up to the 1/256 rate with decreases in total branch length, pod number and seed number occurring as well. This research suggests that florpyrauxifen applied near soybean has a high potential to cause significant damage and growers should consider environmental conditions and have equipment properly calibrated before making an application.

Key words: Florpyrauxifen-benzyl, *Glycine max*, *Oryza sativa*, Off-target, Yield.

Off-Target Florpyrauxifen-benzyl and its Effect on Soybean Yield Components

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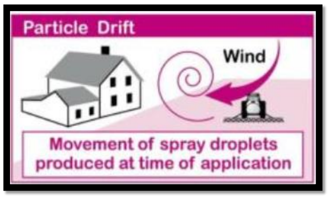
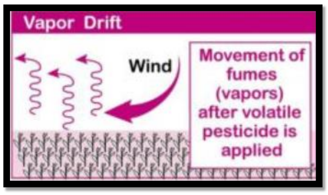
Introduction

Rice (*Oryza sativa* L.) and soybean [*Glycine max* (L.) Merr.] are high value crops that are frequently grown in close proximity to one another in the Southern United States. Many of the herbicides that are applied to rice are not labeled for use in soybean and can result in visual injury and yield loss if deposited on susceptible vegetation. The off-target movement of herbicides can occur via either particle drift or vapor drift.





Florpyrauxifen-benzyl is a synthetic auxin that has activity on select broadleaf, grass, and sedge weeds in rice and was first released by Corteva Agriscience™ for use in the 2018 growing season. While florpyrauxifen has shown to have a low potential for vapor drift it is extremely susceptible to particle drift and injurious to soybean (Schwartz-Lazaro et al. 2017). Concentrations of particle drift solution have also proved to vary greatly, ranging anywhere from 0.01 to 10 percent of the applied rate (Al-Khatib & Peterson 1999). Therefore, a study was conducted to determine at what application timing and what concentrations this herbicide can damage soybean and the impact it has on individual soybean yield components.

Objective

Evaluate florpyrauxifen-benzyl concentration and application timing effects on soybean growth and yield components.

Materials and Methods

- This study was conducted at LSU AgCenter Experiment Stations located near Alexandria and Crowley, Louisiana in 2019.
- **Experimental design:**
  - **Randomized complete block**
    - 4 replications
  - **2 Factors:**
    - **Application timing**: V4-V5; R1-R2 soybean
    - **Herbicide concentration**: Rate titration of florpyrauxifen via serial dilutions (Table 1)
      - Predetermined dicamba concentrations resulting in yield reduction and visual injury were included for comparison (Foster & Griffin 2018)

Table 1: Concentrations of florpyrauxifen and dicamba applied to soybean.

	Florpyrauxifen-benzyl (1x = 29.44 g ai ha^{-1})					Dicamba (1x = 558.94 g ae ha^{-1})	
Concentration	**1/4x**	**1/16x**	**1/64x**	**1/256x**	**1/1024x**	**1/32x**	**1/1000x**
g ai/ae ha^{-1}	7.35906	1.83976	0.45994	0.11499	0.02875	17.50009	0.55893

- Treatments were applied using a CO_2-pressurized backpack sprayer
  - Spray volume: 140 L ha^{-1} @ 276 kPa
  - Plot dimensions: 3.04 m (meters) x 12.19 m
    - Center 2 rows of 4 (76 cm spacing) were treated
- **Data collection:**
  - **Visual injury**: 1,7,14 and 28 DAT (days after treatment)
  - **Plant heights**: 7, 14 and 28 DAT and prior to harvest
  - **Yield component analysis**
    - Total branch length – cm (TBL)
    - Branch number (BRN)
    - Node number (NN)
    - Reproductive node % (RN)
    - Pod number (PN)
    - Seed number (SN)
  - **Soybean yield**: % of NTC (nontreated check)
- **Data analysis**
  - SAS 9.4: Proc GLIMMIX; Fisher's LSD (α=0.05)

Results

- Visual plant injury ranging from 5-100% was observed for soybean treated with 1/1024x concentration of florpyrauxifen and greater at 28 DAT for both application timings (data not shown).
  - 1/4x and 1/16x concentrations of florpyrauxifen at both application timings resulted in total plant death (Images 1 and 2).
- Plant height reductions ranging from 12-100% were observed for all concentration and application timing combinations (data not shown).
- Yield reductions ranging from 12-100% were observed for soybean treated with 1/1024x and greater of florpyrauxifen at both application timings (data not shown)
  - 1/32x of dicamba and 1/64x of florpyrauxifen resulted in 29 and 31% soybean yield reductions, respectively.
- Yield component analysis data is displayed in table 2.
  - 1/4x and 1/16x concentrations of florpyrauxifen applied to soybean resulted in decreases of all yield components.
  - SN was not affected by application timing.
  - 1024x concentrations of florpyrauxifen applied to soybean resulted in hormetic effects on pod number and node number.

Image 1: Soybean treated with 7.35 g ai ha^{-1} of florpyrauxifen 28 days after V4-V5.

Image 2: Soybean treated with 1.84 g ai ha^{-1} of florpyrauxifen 28 days after R1-R2.

Table 2: Yield component analysis for each herbicide concentration and application timing combination. Numbers with an asterisk are significantly different from their respective NTC using Fisher's LSD ($p \le 0.05$).

	V4-V5 Application Timing							R1-R2 Application Timing						
Conc.	**1/4x**	**1/16x**	**1/64x**	**1/256x**	**1/1024x**	**1/32xD**	**1/1000xD**	**1/4x**	**1/16x**	**1/64x**	**1/256x**	**1/1024x**	**1/32xD**	**1/1000xD**
TBL	15*	14*	170	130	132	87*	159	39*	36*	70*	115	150	59*	108
BRN	0.75*	0.69*	3.50	3.50	3.81	2.70	4.5	2.44*	2.75*	2.88*	4.19	4	3.88	3.94
NN	5.63*	5.44*	29.96*	33.88	33.625	22.60*	40.69	13.81*	15*	26.06*	35.06	42.78*	24.13*	32.25
RN	0*	0*	77.51	74.62	64.51	70.28	59.06*	71.07	75.16	73.53	58.55*	69.21	76.64	75.60
PN	0*	0*	37.35	35.75	33	18.86*	30.69	13.88*	15.31*	34.13	32.13	43.21*	30.44	31.25
SN[1]	0*	0*	73.52	75.53	77.79	48.12*	64.22*	-	-	-	-	-	-	-

[1] SN was averaged across both application timings.

Conclusions

Based on the results of this study, concentrations of florpyrauxifen at least 1/256x or greater of the full labeled rate will negatively impact soybean branch formation, node formation, pod production and seed production. Furthermore, concentrations used in this study are classified as feasible particle drift solution concentrations based on Al-Khatib and Peterson's previous research. Therefore, off-target florpyrauxifen can negatively impact individual soybean yield components. This study also supports previous research that states hormetic effects can result from sub-lethal concentrations of auxins being applied to soybean (Belz et al. 2011). In conclusion, applicators must proceed with caution when applying florpyrauxifen to rice crops that are in close proximity to soybean and other susceptible vegetation to avoid unintentional negative effects.

Future Research and Improvements

This study will be repeated in the 2020 growing season to confirm the results obtained in 2019. Also, correlation testing will be performed to determine if all yield components are associated with a yield reduction.

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❷ *Agronomy*

Yield components, photoassimilates and nutrients partitioning in new rice varieties

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ABSTRACT

Nutrient deficiencies, as well as the toxic effects of soils can cause symptoms and changes in the yield components and the distribution of photoassimilates. To assess the effect of deficiencies and nutrient excesses on the partition of assimilates and the components of yield of new commercial varieties with high yield potential a potting test was carried out, NPK deficiencies not being tested. Significant differences between varieties and treatments were found. The "full" treatment that received all the nutrients in adequate amounts was taken as control treatment; while the sulfur-free and zinc-free treatments, as well as the "alkaline", "saline" and "acid" treatments had a lower proportion of roots. Only the treatments without S, without Zn and “saline” had a significantly lower grain yield, related to a smaller number of panicles per pot. The partition of nutrients located in grains, stems and roots was very diverse, N and P with high grain content; K, Ca and Mg in stems and leaves while Fe, Cu, Na, S, Zn and B mostly in roots.

Key words: Soil fertility, Biomass allocation, Grains, Roots, Shoots.

1. Introduction

Fifteen nutrients are considered of the outmost importance for crops: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), boron (B), copper (Cu), molybdenum (Mo), chlorine (Cl), silica (Si) and cobalt (Co). When these elements are not available or are not absorbed by the plant, deficiency occurs and in case of excess toxicity is generated. In each case the plants shows different visual symptoms and the concentrations of nutrients within the plant decrease or are affected.

Rice (*Oryza sativa*) cultivation is carried out in poor or low fertile soils. To this is added the intensification of the crop and the consequent soil depletion. The use of NPK fertilizers is frequent, Zn is applied in some situations, but other essential elements are seldom used. The soils with acidity, salinity and sodicity problems used for rice cultivation produce a decrease in productivity (Quintero, 2018). In general, the root:shoot ratio of crops is inversely proportional to both nutrient and water availability, as plants allocate relatively more photosynthates to their roots under sub-optimal and limiting conditions to increase soil exploration (De Bauw et al., 2019). For Xu et al. (2015) this is attributed mainly to a decrease in the aboveground biomass, rather than an increase in root biomass. Little is known about the effect of nutrient deficiencies or excesses on new modern high yield varieties; less even on smaller essential elements other than NPK.

Therefore, the objective of our work was to evaluate the symptoms of deficiencies and the excesses of less conventional nutrients; as well as to quantify the changes in the partition of photoassimilates and yield components. To reach to know the distribution of nutrients in the roots, stems and grains is of equal importance

2. Material and Methods

The test was carried out under greenhouse conditions at the Facultad de Ciencias Agropecuarias (UNER) in 2017/2018. Pots with 1.8 kg sand were used and before planting, the nutrients required, in solid and liquid form, were added to each pot for the treatments proposed. Nutritious solutions were made and incorporated into the sand by mixing homogeneously and then planting rice. Fifteen rice seeds were sown in each one, leaving a total of 3 plants per pots until harvest. The varieties used were IRGA 424, Memby Porá INTA CL and Kirá INTA.

A treatment that contained all the nutrients in appropriate amounts was performed and was called "FULL". This treatment received: N 1608 mg kg^{-1}, P 96 mg kg^{-1}, K 476 mg kg^{-1}, Ca 423 mg kg^{-1}, Zn 31 mg kg^{-1}, Mn 51 mg kg^{-1}, Fe 33 mg kg^{-1}, Cu 4 mg kg^{-1}, B 4 mg kg^{-1}, Mo 0,107 mg kg^{-1}, Si 2572 mg kg^{-1}, Cl 192 mg kg^{-1} y Na 0,051 mg kg^{-1}. NPK deficiencies were not tested. Deficiencies of Ca-Mg-S, etc. were evaluated omitting their application in each treatment called with the minus sign.

Three more treatments were performed to see the effect of excess over "full" condition. One called "ACID", which received: $AlCl_3.6H_2O$, Fe-EDDHA, $FeCl_3.6H_2O$, $FeNH_4(SO_3)_2.12H_2O$, $MnCl_2.H_2O$ and HCl (Al 85 mg kg^{-1}, Fe 204 mg kg^{-1}, Cl 824 mg kg^{-1}, S 375 mg kg^{-1}). One called "ALKALINE" with an extra supply of: $CaCO_3$ and $MgCl_2.6H_2O$, (Ca 4449 mg kg^{-1} y Mg 332 mg kg^{-1}). Finally another treatment called "SALINE" with the addition of NaCl (Na 1229 mg kg^{-1}). Thus 14 treatments were realized. At the beginning of the tillering the pots were flooded placing them with water in larger individual containers. The flooded sand pH and the electrical conductivity (EC) of the "full", "acid" "alkaline" and "saline" treatments were pH: 6.5, 6.3, 6.9 and 6.8; EC: 0.38, 1.8, 2.0 and 1.8 dS m^{-1} respectively.

At harvest time, the stems+leaves, grains and roots were separated to determine dry matter. The yield components (panicles, fertile spikelets, grain weights) were determined and statistical analyzes were performed. The roots, stems, leaves and grains of the "full" treatments were chemically analyzed to determine the absorbed nutrients.

3. Results and Discussion

Significant differences were observed between the 3 varieties (Table 1). IRGA 424 and Memby Porá (long fine grain) showed similar characteristics in terms of number of panicles, spikelets per panicle and grain weight. On the other hand, Kirá (double grain) presented a smaller number of panicles, with a greater number of grains per panicle and of greater weight. However, the ratio grains/stems+leaves/roots was similar between varieties: 1/0.73/2.20 for IRGA 424, 1/0.61/1.92 for Memby Porá and 1/0.93/1.91 for Kirá. It is noticeable that underground biomass had a magnitude similar to aerial biomass.

Table 1. Yield components and biomass partitioning by variety

Variety	n	Stems+leaves (g pot^{-1})	Roots (g pot^{-1})	Panicles pot^{-1}	Spikelets $panicles^{-1}$	Unfilled grains (%)	1000 grains (g)	Grain Yield (g pot^{-1})
IRGA 424	14	22.3 b	69.9 b	21 b	73 a	11.9 a	22.1 b	31.8 b
Memby Porá	14	17.9 a	56.7 a	18 b	88 b	9.3 a	20.9 a	29.5 ab
Kirá	14	25.3 b	52.0 a	10 a	91 b	23.1 b	36.6 c	27.2 a

Means with a common letter are not significantly different (p <= 0.05). Test: LSD Fisher Alpha = 0.05.

Significant differences were also observed between treatments (Table 2). The "full" treatment showed the highest biomass values, the highest number of panicles per pot, with 92 grains per panicle, resulting in a grain yield of 34.7 g pot^{-1}, thus compensating for the high sterility found. The treatment without Si was similar.

The treatment without S was the most affected one. It showed a significant reduction in biomass, half of the panicles per pot than the "full" treatment and a significant reduction in grain yield (Figure 1). The second nutrient with high effect was Zn. The biomass of roots and stems+leaves was significantly lower. Although the number of panicles was not markedly reduced, it showed a low number of spikelets per panicle (Table 1).

The ratio grains/stems+leaves/roots was 1/0.88/2.59 for "full" treatments, while for "-S" and "-Zn" treatments it was 1/0.90/2.23 y 1/0.75/1.79 respectively. The treatments of "excesses" also showed a change in the proportions of the biomass of the plants with a strong reduction in the roots. The ratio was 1/0.84/1.67 for "acid", 1/0.70/1.59 for "alkaline" and 1/0.69/1.61 for saline treatments.

Table 2. Yield components by treatment.

Treatments	n	Panicles pot^{-1}	Spikelets panicles^{-1}	Unfilled grains (%)	1000 grains (g)	Grain Yield (g pot^{-1})	Harvest Index (%)
Full	3	22 d	92 ab	19.3 c	25.7 abc	34.7 d	53.6 ab
- Ca	3	19 cd	87 ab	16.1 abc	27.0 abc	33.1 cd	60.3 bcd
- Mg	3	14 abc	76 ab	18.3 bc	24.3 a	28.1 abcd	55.6 abcd
- S	3	11 ab	82 ab	17.7 abc	25.2 ab	20.5 a	52.1 a
- B	3	19 cd	86 ab	13.9 abc	25.7 abc	31.0 bcd	60.8 cd
- Mn	3	17 abcd	85 ab	19.3 c	27.4 bc	29.6 bcd	60.7 cd
- Zn	3	16 abcd	72 a	12.3 abc	26.7 abc	24.2 ab	58.0 abcd
- Cu	3	16 abcd	88 ab	14.1 abc	27.6 bc	30.2 bcd	58.0 abcd
- Fe	3	15 abcd	87 ab	11.4 abc	27.0 bc	28.7 abcd	58.4 abcd
- Mo	3	18 cd	87 ab	11.1 ab	27.1 bc	34.9 d	59.6 bcd
- Si	3	18 bcd	77 ab	16.2 abc	26.9 abc	32.1 bcd	56.9 abcd
Acid	3	18 abcd	78 ab	12.4 abc	28.1 c	32.9 cd	54.0 abc
Alkaline	3	11 a	100 b	14.8 abc	25.9 abc	27.2 abcd	61.5 d
Saline	3	15 abcd	80 ab	10.0 a	26.7 abc	25.7 abc	59.1 bcd

Means with a common letter are not significantly different (p <= 0.05). Test: LSD Fisher Alpha = 0.05.

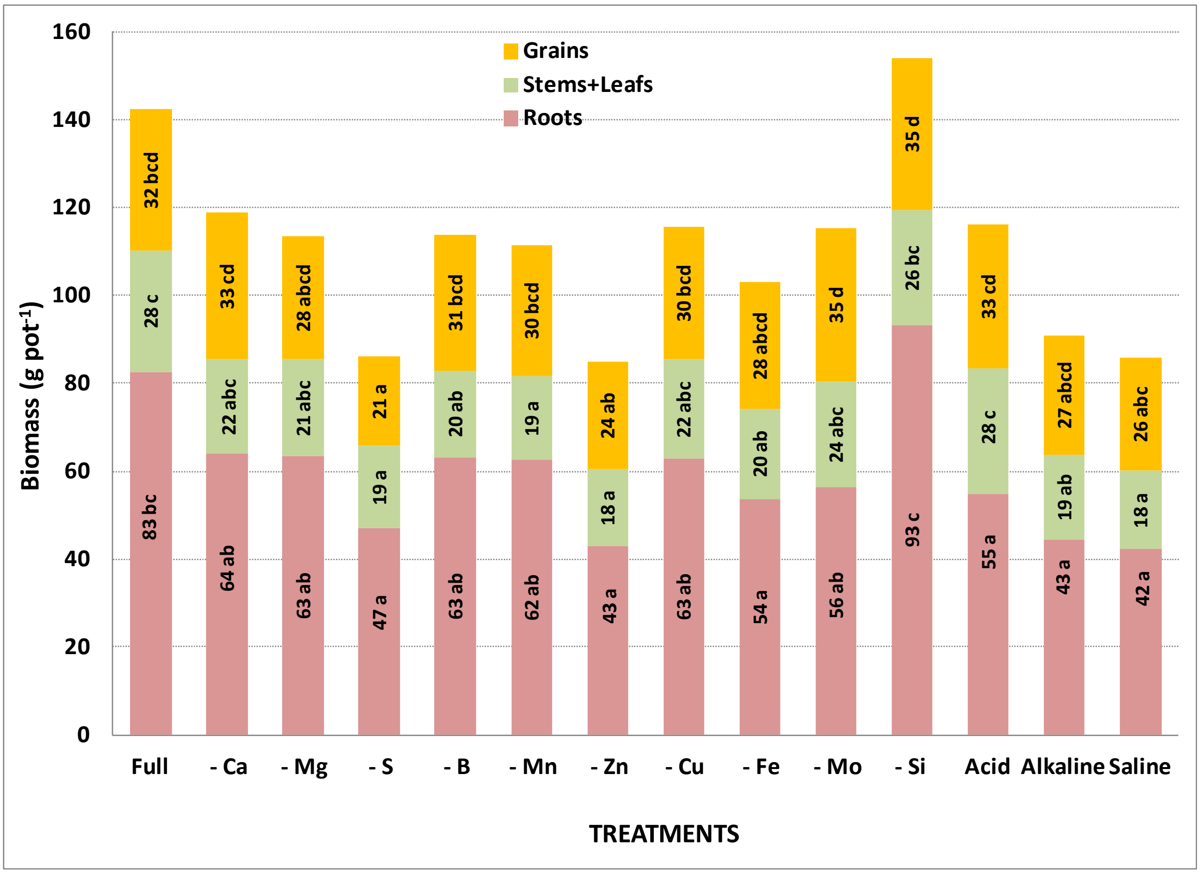

Figure 1. Biomass of roots, stems+leaves and grains for all treatments. Average of the 3 varieties.

The distribution of nutrients in different parts of the plant varied with the particular element considered (Figure 2). Although the root biomass was close to 50 % of the total biomass, the proportion of some nutrients (N-P-K-Mg) in the root was less than 40 %. Other elements such as Ca, S, Zn, Cu and Na exceeded 50 % at the root, highlighting Fe with more than 90 %. The elements with high proportion in grains were N and P followed by S and Zn; those left in the stubble were K, Ca, Mg, Mn and Si.

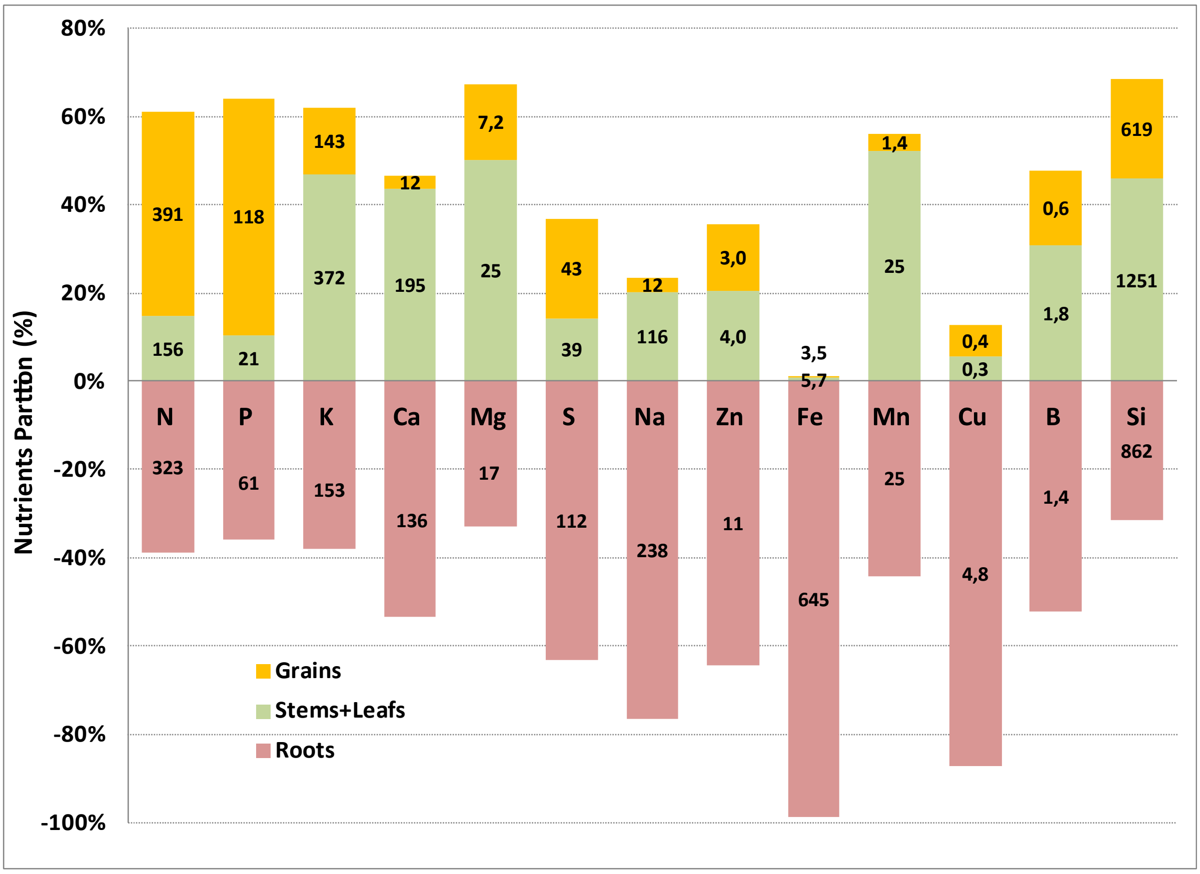

Figure 2. Nutrients partition uptake in roots, stems+leaves and grains, for “full” treatments. Average of the 3 varieties. Number inside the bar represents the amount of nutrient absorbed in mg or µg per pot. Roots with negative sign for better visualization.

Conclusions

It is known that NPK deficiency causes a severe reduction in rice yield. In this work it has been observed how the deficiency of S or Zn and the saline-alkaline soil conditions can affect the growth and productivity of rice. Under these conditions, there is growth reduction of plants, with a lower proportion of roots and lower panicles emission resulting in a lower yield. Lastly, the nutrients allocation observed was very diverse.

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Yield components, photoassimilates and nutrients partitioning in new rice varieties

UNER

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Introduction

Nutrient deficiencies, as well as the toxic effects of soils can cause symptoms and changes in the yield components and the distribution of photoassimilates. The root:shoot ratio of crops is inversely proportional to both nutrient and water availability (De Bauw et al., 2019; For Xu et al., 2015). Little is known about the effect of nutrient deficiencies or excesses less essential elements other than NPK.

Objective

Evaluate the symptoms of deficiencies and the excesses of less conventional nutrients; as well as quantify the changes in the partition of photoassimilates and the yield components. Also, know the distribution of nutrients in the roots, stems and grains.

Material and Methods

Greenhouse conditions at the Facultad de Ciencias Agropecuarias (UNER) in 2017/2018. Varieties: IRGA 424, Memby Porá INTA CL and Kirá INTA. A treatment that contained all the nutrients in appropriate amounts was performed and was called "FULL". Deficiencies of Ca-Mg-S, etc. were evaluated omitting their application in each treatment called. The yield components and dry matter were determined. The "full" treatments were chemically analyzed to determine the absorbed nutrients.

Results

Significant differences were observed between the 3 varieties (Table 1). IRGA 424 and Memby Porá showed similar characteristics. The ratio grains/stems+leaves/roots was similar between varieties: 1/0.73/2.20 for IRGA 424, 1/0.61/1.92 for Memby Porá and 1/0.93/1.91 for Kirá.

Table 1. Yield components and biomass partitioning by variety.

Variety	n	Stems+leaves (g pot^{-1})	Roots (g pot^{-1})	Panicles pot^{-1}	Spikelets panicles^{-1}	Unfilled grains (%)	1000 grains (g)	Grain Yield (g pot^{-1})
IRGA 424	14	22,3 b	69,9 b	21 b	73 A	11,9 a	22,1 b	31,8 b
Memby Porá	14	17,9 a	56,7 a	18 B	88 B	9,3 a	20,9 a	29,5 ab
Kirá	14	25,3 b	52,0 a	10 a	91 B	23,1 b	36,6 c	27,2 a

Significant differences were also observed between treatments. The FULL treatment showed the highest biomass values, number of panicles per pot, grains per panicle and grain yield of per pot (Table 2). The sulfur-free and zinc-free treatments, as well as the "alkaline", "saline" and "acid" treatments, had a lower proportion of roots. But only the treatments without S, without Zn and "saline" had a significantly lower grain yield, related to a smaller number of panicles per pot (Figura 1 and 2).

Table 2. Yield components by treatment.

Treat.	N	Panicles pot^{-1}	Spikelets panicles^{-1}	Unfilled grains (%)	1000 grains (g)	Grain Yield (g pot^{-1})	Harvest Index (%)
Full	3	22 d	92 ab	19,3 c	25,7 abc	34,7 d	53,6 ab
- Ca	3	19 cd	87 ab	16,1 abc	27,0 abc	33,1 cd	60,3 bcd
- Mg	3	14 abc	76 ab	18,3 bc	24,3 a	28,1 abcd	55,6 abcd
- S	3	11 ab	82 ab	17,7 abc	25,2 ab	20,5 a	52,1 a
- B	3	19 cd	86 ab	13,9 abc	25,7 abc	31,0 bcd	60,8 cd
- Mn	3	17 abcd	85 ab	19,3 c	27,4 bc	29,6 bcd	60,7 cd
- Zn	3	16 abcd	72 a	12,3 abc	26,7 abc	24,2 ab	58,0 abcd
- Cu	3	16 abcd	88 ab	14,1 abc	27,6 bc	30,2 bcd	58,0 abcd
- Fe	3	15 abcd	87 ab	11,4 abc	27,0 bc	28,7 abcd	58,4 abcd
- Mo	3	18 cd	87 ab	11,1 ab	27,1 bc	34,9 d	59,6 bcd
- Si	3	18 bcd	77 ab	16,2 abc	26,9 abc	32,1 bcd	56,9 abcd
Acid	3	18 abcd	78 ab	12,4 abc	28,1 c	32,9 cd	54,0 abc
Alkaline	3	11 a	100 b	14,8 abc	25,9 abc	27,2 abcd	61,5 d
Saline	3	15 abcd	80 ab	10,0 a	26,7 abc	25,7 abc	59,1 bcd

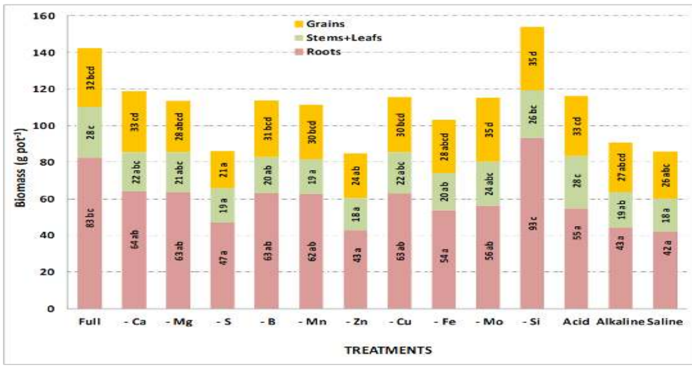

Figure 1. Biomass of roots, stems+leaves and grains for all treatments. Average of the 3 varieties.

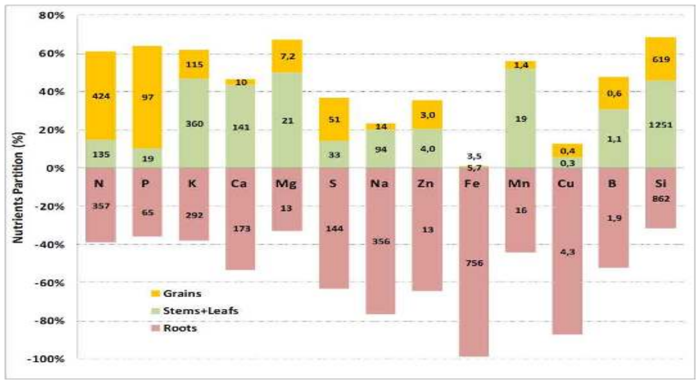

Figure 2. Nutrients partition uptake in roots, stems+leaves and grains, for "full" treatments (3 varieties).

Conclusions

The partition of nutrients located in grains, stems and roots was very diverse. N and P with high grain content; K, Ca and Mg in stems and leaves. While Fe, Cu, Na, S, Zn and B mostly in roots.

Effects of Deep Seeding on Weed Management and Crop Response in California Rice Systems

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ABSTRACT

California rice (*Oryza sativa* L.) is grown as a monoculture, seeded by air into permanently-flooded basins. Decades of overreliance on a small number of herbicides have led to widespread herbicide resistance. The objectives of this study were to evaluate the weed management and crop physiology feasibilities of deep-drilled rice. Seeding deep should delay stand emergence and allow use of broad-spectrum herbicides on emerged weeds, without injuring the rice. This would make additional modes of action available for the mitigation of herbicide resistance. Seed of *cv.* M-206 and M-209 were dry-drilled to 3cm and 6cm, in a split-split-plot design with four herbicide programs, over 2018-2019. Herbicide programs centered on using glyphosate as a burndown treatment prior to rice emergence. Irrigation was by flushing every seven days until 28DAP, whereupon 10cm flood was established for the remainder of the season. Herbicides and required adjuvants were applied by CO_2-pressuized backpack sprayer with 8003VS flat-fan nozzles at 187 L ha^{-1}. Glyphosate was applied at 870g ae ha^{-1} just as rice was spiking. Glyphosate alone was able to control >60% of grasses and >80% of sedges. Treated plots were weed-free. Rice first-leaf tips died back after glyphosate application, but stands developed normally. Stands at 6cm planting decreased by 15.5% and 5.3% in 2018, but increased by 3.8% or were unchanged in 2019, for M-206 and M-209 respectively. Stand reductions were largely compensated for by increased tillering. Yields were not affected by 6cm depth for either *cv.* in 2018, while in 2019 they increased by 5% or decreased by 3.4% for M-206 and M-209, respectively. Yields compared to nearby water-seeded fields were 2-22% and 3-11% higher in 2018 and 2019, respectively. We found that excellent weed control and competitive yields are achievable with this program, given good scouting and field management.

Keywords: Herbicide resistance, rice, drill-seeding

Cyperus difformis ALS cross-resistance levels and target-site characterization

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ABSTRACT

Populations of *Cyperus difformis* L. (smallflower umbrella sedge) resistant to the ALS inhibitor bensulfuron-methyl were discovered in California rice fields in 1994, four years after its release. Since then, *C. difformis* populations resistant to each ALS inhibitor registered for California rice have been identified. To adequately inform growers of their *C. difformis* management options, and inform the rice industry of the magnitude of the ALS resistance issue, a comprehensive characterization of the scale, distribution, and mechanisms of ALS inhibitor cross-resistance is required. Sixty-two populations of *C. difformis* suspected to be ALS inhibitor resistant were collected from throughout the region, and screened for cross-resistance. Herbicides administered were bensulfuron-methyl, halosulfuron-methyl, bispyribac-sodium, and penoxsulam, applied at discriminating rates of 70.1 & 210.3, 70.1 & 210.3, 37.4 & 112.2, and 42 & 126g ha^{-1}, respectively. Six populations of *C. difformis* confirmed ALS cross-resistant were self-pollinated, and S-1 seed were tested for resistance levels via dose-response with the abovementioned herbicides, with rates ranging from 13.3-852, 13.3-852, 7.1-455, and 8-510g ai ha^{-1}, respectively. All herbicide treatments were administered with required adjuvants in a compressed-air singletrack spray booth fitted with one 8002EVS tip, delivering 187L ha^{-1}. Screening revealed six major patterns of ALS inhibitor cross-resistance, with no apparent geographic distribution pattern. Each population tested was resistant to bensulfuron-methyl, with average survival of 75% at the lower rate. Twenty-one populations were susceptible to halosulfuron-methyl, even though it and bensulfuron-methyl are sulfonylureas. Only three populations showed resistance to penoxsulam; two were resistant to all four herbicides. Dose-response confirmed that the majority of resistance in the tested populations was dose-dependent, suggesting nontarget-site resistance mechanisms. Two populations showed high survival at the highest herbicide rates, with RI's >200, and therefore may possess insensitive ALS enzymes. Studies to elucidate target- and nontarget mechanisms of resistance are underway.

Keywords: *Cyperus difformis,* ALS inhibitors, cross-resistance

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Evidence for metabolic ALS inhibitor cross-resistance in *Cyperus difformis* in California

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Background

- *Cyperus difformis* L. (CYPDI) is a major weed in California rice.
- Control of sedges has relied heavily on acetolactase synthase (ALS) inhibiting herbicides for decades.
- Populations of CYPDI resistant to ALS inhibitors are now widespread.
- Previous research identified six major patterns of ALS cross-resistance in California populations of CYPDI.
- Patterns suggest multiple resistance pathways (*Fig 1*).
- Metabolic resistance to ALS inhibitors is often due to enhanced cytochrome P450-mediated herbicide degradation.
- Many P450s are suppressed by the insecticide malathion.

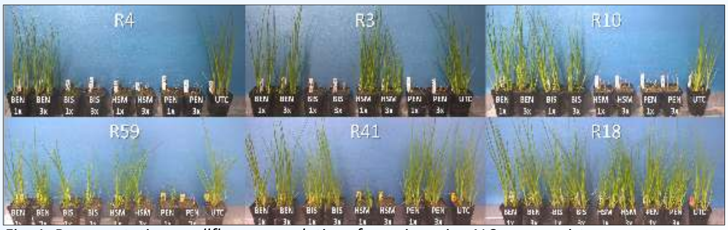

Fig. 1. Representative smallflower populations from six major ALS cross-resistance patterns.

Objectives

1. **Determine resistance levels of smallflower populations from six patterns of ALS cross-resistance.**
2. **Detect evidence of metabolic ALS resistance *in planta* via malathion.**

Experimental Design

- Studies were conducted in-greenhouse at UC Davis.
- CYPDI populations from six patterns of ALS cross-resistance were selfed to S1.
- All treatments were applied with a booth track sprayer with an 8002EV nozzle.

— 1. ALS dose-response —

- Dose-response study to determine ALS resistance levels, and if resistances are dose-dependent.
- 0.125x - 12x label rates applied to resistant (R) populations; 0.03x - 1x rate applied to SUS.
  1. Bensulfuron-methyl
  2. Halosulfuron-methyl + 0.25% v/v NIS
  3. Bispyribac-sodium + 2% v/v UAN
  4. Penoxsulam + 2.5% v/v COC
- Estimated visual injury measured three weeks after treatment (3WAT).
- Resistance indices (RI) were calculated from dose required to reduce survival by 50% (LD_{50}).

— 2. Malathion P450 antagonism—

- Study to determine if enhanced P450 metabolism is involved in CYPDI ALS resistance. Malathion should suppress p450s and reverse resistance, causing increased injury or death.
- Malathion applied at 1.5 kg ha^{-1}, 16h before and 6h after herbicides.
- Herbicides applied at 1x label rate.
- All treatments included 0.25% v/v NIS.

1. UTC
2. Malathion fb malathion
3. Bensulfuron
4. Halosulfuron
5. Bispyribac
6. Penoxsulam
7. Malathion fb bensulfuron fb malathion
8. Malathion fb halosulfuron fb malathion
9. Malathion fb bispyribac fb malathion
10. Malathion fb penoxsulam fb malathion

- Estimated visual injury and drymass reduction measured at 3WAT.
- Model fit and means comparisons were generated with *gamlss* and *ggeffects* packages in R.

Acknowledgements

This research was conducted with support from the California Rice Research Board (CRRB), the D. Marlin Brandon rice research fellowship, and the F. Dan Hess weed research endowment

Results & Discussion

— 1. ALS dose-response —

- Most observed resistance was dose-dependent (*Fig 2*), suggesting nontarget resistance mechanisms prevalent, particularly for bensulfuron.
- R18 and R41 are strongly resistant to ALS inhibitors, based on RI's.
  - Possible target-site (TS) alterations present for either population.
  - R41 was S to halosulfuron; metabolic and TS mechanisms may be present.
- Injury rate levels off with highest herbicide rates in some populations.
  - Possible heterozygous TS resistance, or weak homozygous resistance.

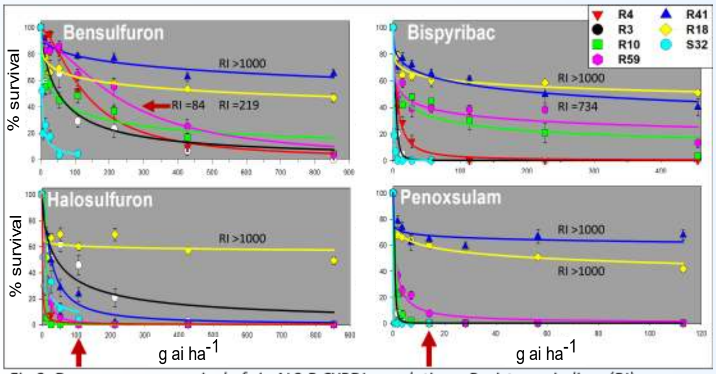

Fig 2. Dose-response survival of six ALS-R CYPDI populations. Resistance indices (RI) calculated by dividing 50% lethal dose (LD_{50}) for ALS-R populations by LD_{50} of SUS.

— 2. Malathion P450 antagonism—

- Malathion effect was most pronounced with bensulfuron, least pronounced with halosulfuron (*Fig 3*). Both are sulfonylureas; sulfonylurea degradation has many known pathways.
- Effect on bispyribac and penoxsulam resistance is limited. R18 and R59 seem to be the most affected by malathion addition. R59 was susceptible to penoxsulam in screening and dose-response studies, using same seedlot.
- Malathion does not inhibit all known P450s, thus metabolic resistance may be mediated by other P450s or possibly glutathione-S-transferase (GST).
  - GST resistance to ALS inhibitors appears to be rare in published works.
  - Piperonyl butoxide P450 inhibition could evince other P450s involved.

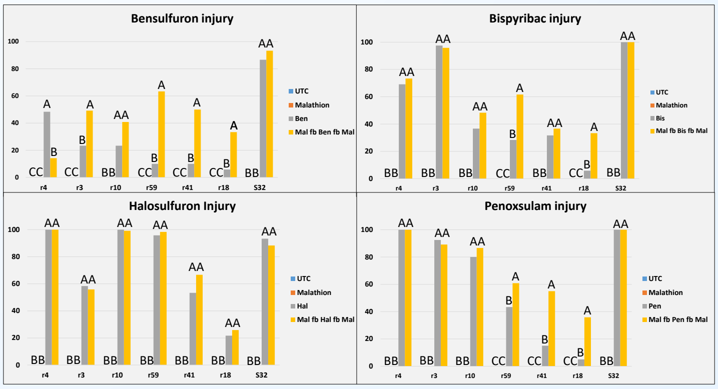

Fig 3. Malathion inhibition of ALS inhibitors in CYPDI. Letters represent Tukey means separation at α = 0.05 for each population x herbicide.

Conclusions and Future Work

- Most ALS resistance in study populations appears to be nontarget, though it is not presently obvious that enhanced metabolism is the only factor.
  - ^{14}C uptake and translocation study should determine whether other nontarget resistance is occurring.
- Mass spectrometry studies will determine metabolite profiles for each *population x herbicide*, allowing determination of similar P450 pathways.
- Sequencing ALS subunit gene for all populations will elucidate whether TS insensitivity is a factor in observed resistance.

Evaluation of Nitrogen Management in Furrow Irrigated Rice

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ABSTRACT

Furrow irrigated rice (*Oryza sativa* L.) production (FIR) in the mid-south has increased in popularity over the last 3-years. In Louisiana alone, FIR hectares have increased from 567 in 2017, to 2007 hectares in 2018, and to 6243 ha in 2019. Hectares of FIR in Arkansas were estimated to exceed 43,740 in 2019. Interest in FIR and the potential for it to be an insurable practice in 2020 will further increase hectares in the coming year.

Nitrogen (N) management in drill-seeded, delayed flood rice production in Louisiana typically utilizes a 2-way split application, where two-thirds of the seasonal N need is applied pre-flood and the remainder of the seasonal N need is applied at mid-season. In this system, the application of the pre-flood urea fertilizer on dry ground and the timely establishment of the permanent flood stabilizes the ammonium-N, which maximizes the nitrogen use efficiency (NUE). The application of N fertilizers when utilizing furrow irrigation is not as efficient due to the repetitive wetting and drying of the soil. Significant losses of N can come from both ammonia volatilization and nitrification-denitrification. The objectives of the current studies were three-fold: 1) to compare N fertilizer rates in a when grown under FIR or traditional flooding; 2) evaluate single and split N fertilizer application timings; and 3) evaluate the effectiveness of urea treated with n-butyl thoiphosphoric trimide (NBPT) and urea treated with NBPT plus dicyandiamide (DCD) in FIR.

Fertilizer N rate trials utilized two management practices (traditional flooding and FIR) and six N rates (0, 101, 134, 168, 202, and 235m kg ha^{-1}). Fertilizer time of application trials utilized a single pre-flood, 2-way split, 3-way split, and a 4-way split applications at N rates of 155 and 206 kg N ha^{-1}. The N fertilizer source trial compared urea treated with NBPT (Agrotain Advanced) and NBPT+DCD urea (SuperU), three N rates (0, 109, and 155 kg N ha^{-1}) and three application methods (single application, 2-way split, and 3-way split). Trials were conducted in 2018 and 2019 at the H.R.C. Rice Research Station in Crowley, LA on a Crowley silt loam soil and at the Northeast Research Station in St. Joseph, LA on a Sharkey clay in 2019.

In 2018 on the silt loam soil, the optimal N rate was determined for CLXL745 at an N rate of 168 kg ha^{-1} when grown using FIR as compared to 101 kg ha^{-1} when grown in a delayed flood system. The optimal N rate for CL153 was 168 kg ha^{-1} when grown under FIR and traditional flooding. The optimal application timing for CLXL745 was achieved when using the 3-way split application at the rate of 155 kg N ha^{-1}. The optimal N application method for CL153 when growing under FIR was also the 3-way split when using the 155 kg N ha^{-1} rate.

In 2019 on the silt loam soil, the optimal N rate was determined for CLXL745 and CL153 at an N rate of 101 kg ha^{-1} when grown using FIR and traditional flooding. The optimal N rate for CLXL745 was achieved when using the 2-way split application at both the 155 and 206 kg ha^{-1} rates. The optimal N application method for CL153 when growing under FIR was the 4-way split when using the 155 kg ha^{-1} N rate and the 3-way split when using 206 kg ha^{-1}. The N source trial results indicated that the single, 2-way split, and 3-way split applications were not significantly different from each other; however, slight increase in yield was observed as the number of N applications increased. The NBPT-urea (urease inhibitor only) and the SuperU (urease inhibitor and nitrification inhibitor)

fertilizer sources were not significantly different from each other; although, the SuperU had higher numerical yield averages.

Rates, timing, and the use of enhanced efficiency fertilizers varied across soils and years due to variations in environmental conditions at and after fertilization each year. Further research with N rates, timing, and enhanced efficiency fertilizers is needed before FIR best management practices a can be made.

Key words: Furrow Irrigated Rice (FIR), Nitrogen (N), Enhanced Efficiency Fertilizers.

Comparison of Unmanned Aerial System and Active Crop Canopy Sensors Vegetative Index to Estimate Rice Grain Yield Potential

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ABSTRACT

Nitrogen (N) is the most essential nutrient to rice having a profound effect on the outcome of grain yield and quality. Yield potential is one of the three components used to produce an algorithm to accurately estimate mid-season N fertilization rates in rice. Vegetative indices are a widely used, consistent indicator of yield potential. The GreenSeeker (active light sensor) is the most common remote sensing tool used to collect vegetative indices measurements. Unmanned aerial systems (UAS) is another remote sensing tool that has shown the possibility to collect vegetative indices measurements. However, UAS are mounted with a passive light source sensor which can cause variability in data from climatic conditions during the time of data collections. It's still to be determined whether the UAS can be used to collect vegetative indices as the GreenSeeker has done. The objectives of this study were: 1) Compare the UAS and GreenSeeker derived vegetative indices and 2) Compare the ability of the UAS and GreenSeeker derived vegetative indices to estimate rice grain yield potential. This research was conducted in 2017, 2018, and 2019 at five locations in Louisiana. Rice cultivars were treated with eight pre-flood N rates and hybrids were treated with six pre-flood N rates. Remote sensor data was collected between panicle initiation and panicle differentiation using a GreenSeeker and UAS mounted with the MicaSense multispectral sensor. All three years of data showed the two remote sensors vegetative indices to be correlated with each other. However, the UAS remote sensor data didn't produce the same relationship with yield as the GreenSeeker data. Further research will need to be conducted to determine if a reliable relationship between the two remote sensors and yield can be formed in order to improve the predictability of mid-season N requirements in rice.

Key words: rice, nitrogen, *Oryza sativa*, unmanned aerial system (UAS)

Intensification alternatives to rice-pasture systems: energy use efficiency

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ABSTRACT

Agricultural ecosystems provide the food, fiber and fuel needed for population. Achieve high efficiencies and low energy consumption are necessary to achieve sustainable systems. Rice in Uruguay has historically rotated with pastures. The aim of this study was to evaluate different intensification ways on energy return on investment (EROI), energy input (EI) and energy output (EO) for four rotation systems. Systems were continuous rice (RC); rice-soybean (R-S) and rice-pasture, with pasture for 1.5 years (R-PS); or 3.5 years, (R-PL); all treatments included cover crops during winter. Data from a field experiment conducted since 2012 corresponding to harvest 2015-2016 and 2016-2017 were used. Life cycle analysis methodology was used, study boundaries were gate to gate and functional unit was MJ ha^{-1} of rice grain, soybean grain and meet production. Systems R-PS and RC decrease EROI by 8% and 6.5% respectively compared to R-PL (6.1 MJ MJ^{-1}), Rice rotating with soybean achieved the highest EROI (7.2 MJ MJ^{-1}). Energy output in systems without perennial pastures was 74% higher than those that rotate rice and pastures (73,000 MJ (ha yr)$^{-1}$). In contrast, R-PL and R-PS systems presented 40% less EI than the R-S and RC systems (20,600 MJ (ha yr)$^{-1}$). Include shorter pastures or realize rice monoculture as a way of rice-pasture intensification implied a decrease in energy efficiency, only rice rotating with soybean improve the energy efficiency. However, R-PL was the system that had the lowest energy inputs, which it makes more sustainable system in terms of energy.

Key words: rice, EROI, rotations, sustainability, food production.

Intensification alternatives to rice-pasture systems: energy use efficiency

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Introduction

Agricultural ecosystems provide the food, fiber and fuel needed for population.

Achieve high efficiencies and low energy consumption are necessary to achieve sustainable systems.

Rice in Uruguay has historically rotated with pastures.

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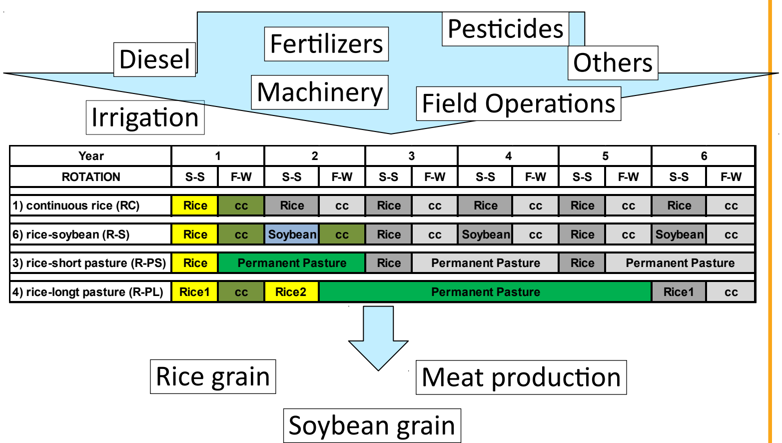
Objective

The aim of this study was to evaluate different intensification ways on energy return on investment (EROI), energy input (EI) and energy output (EO) for four rotation systems.

Material and Methods

Figure 1. Uruguay landmark and LAC map and an aerial picture of the rice-based long-term experiment rotation systems.

- Data from a field scaled long term experiment conducted since 2012 corresponding to harvest 2015-2016 and 2016-2017 were used.
- Life cycle analysis methodology was used, study boundaries were gate to gate and functional unit was MJ ha-1 of rice grain, soybean grain and meet production.



Year	1		2		3		4		5		6	
ROTATION	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W
1) continuous rice (RC)	Rice	cc	Rice	cc	Rice	cc	Rice	cc	Rice	cc	Rice	cc
6) rice-soybean (R-S)	Rice	cc	Soybean	cc	Rice	cc	Soybean	cc	Rice	cc	Soybean	cc
3) rice-short pasture (R-PS)	Rice	Permanent Pasture			Rice	Permanent Pasture			Rice	Permanent Pasture		
4) rice-longt pasture (R-PL)	Rice1	cc	Rice2	Permanent Pasture							Rice1	cc

Figure 2. Rotation systems, inputs used, and main output products evaluates in the long-term experiment

Results

Table 1. Mean values ± standard deviation and number of replicate (n) of physical production of rice grain, soybean grain (kg ha^{-1}) and pastures dry matter; and estimated beef production kg (ha yr.)$^{-1}$

Rotation*	Rice	Soybean	Forage	Meat
R -PL	10,103 ± 943 (12)		6,636 ± 678 (18)	294 ± 30
R -PS	10,276 ± 792 (6)		5,159 ± 1,169 (6)	221 ± 50
R-S	10,512 ± 534 (6)	2,868 ± 797 (6)		
Rc	9,741 ± 572 (6)			

*R –PL: rice and long pastures; R –PS: rice and short pastures; R-S: rice and soybean; Rc: continuous rice.

Table 2. Energy information expressed in MJ (ha yr^{-1})for mean value and standard deviation of invested energy and produced energy in different rice rotation systems.

Rotation	Energy input	Energy output
R -PL	10,607	64,540 ± 2,309 D
R –PS	14,500	80,697 ± 6,117 C
R-S	15,153	109,803 ± 11,279 B
Rc	26,117	149,158 ± 8,765 A

Values followed by the different letter are significant different for a P<0.05

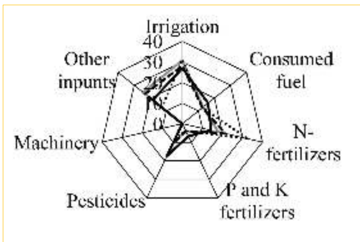


Figure 3. Distribution of energy invested in four rice production systems expressed in percentage unit. Continuous rice (RC, black points); rice-soybean (R-S, black line); rice, and short time of pastures (R-PS, segmented line) and rice long pasture (R-PL, grey line).

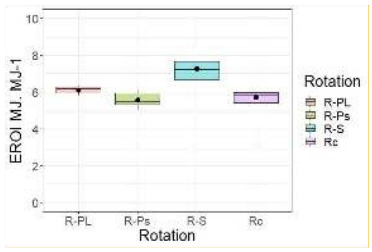


Figure 4. Energy return on investment (EROI) expressed in MJ MJ^{-1} in different rice rotation systems. Continuous rice (RC); rice-soybean (R-S); rice and short pastures (R-PS) and rice and long pasture (R-PL).

Conclusions

Include shorter pastures or realize rice monoculture as a way of rice-pasture intensification implied a decrease in energy efficiency, only rice rotating with soybean improve the energy efficiency. However, R-PL was the system that had the lowest energy inputs, which it makes more sustainable system in terms of energy.

Acknowledgments

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Assessment of Yield Gaps Using Field-Level Data in Uruguay

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ABSTRACT

Understanding yield gaps and the management practices contributing to them is key for enhancing food security and farmers economic viability . Although rice is an important food crop worldwide, yield gaps remain less investigated in South American rice systems, particularly using field-level farmer data. In this study, we evaluated attainable yield gaps and explanatory crop management factors for rice production in Uruguay using field-level records from 2012 to 2017, covering approximately 70,000 ha (40% of total rice area). Machine learning algorithms were employed due to the large size of the database (approx. 3900 observations) and number of predictor variables (15 management practices or field characteristics). The mean annual attainable yield gap ranged from 19% to 22% in fields with conventional cultivars and from 12% to 17% in fields with hybrid cultivars. Early planting was identified by Random Forest as the most influential variables for reducing yield gaps in both conventional and hybrid fields, while germination and previous crop is uniquely influential in conventional and hybrid field, respectively. The package of uniformity at germination stage plus early planting and effective weed management were summarized by classification and regression trees as a strategy for managing suboptimal fields. This study highlights the use of large-scale field data to quantify yield gaps and develop strategies for improving agricultural productivity.

Key words: rice, yield gaps, field-data, machine learning algorithms

Assessment of Yield Gaps in High-Yielding Rice Systems in Uruguay Using Field-Level Data

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Background & Introduction

- Productivity of Uruguay rice system has increased drastically, reaching 3rd highest of the world.
- Continuous improvement in yield is demanded by both producer and miller.
- Understanding field-level constraints to production will help develop effective research targets.
- Concept of closing the yield-gap between the highest-yielding farms and average may provide more benefits than increasing yield of top-yielding farms, which has associated economic and environmental costs.

Objectives

1. Determine influential factors controlling yield gaps in hybrid and conventional variety fields.
2. Identify context-specific management strategies of top-yielding farmers within different field potential categories.

Dataset

1. Field-level records for around 70,000 ha of rice production area in Uruguay produced by SAMAN, a major rice miller.
2. 6 seasons, covering over 40% of total rice planning area.

Variable	Type	Unit	Description
FieldPotential	Categorical	-	The subjective determination of field productivity by cooperative agronomists
FieldSize	Numeric	Ha	Total planted area of the field
Germination	Categorical	-	The uniformity of seedling establishment, determined by the cooperative agronomists
IrrigationTiming	Numeric	day	Number of days between planting and irrigation
KRate	Numeric	Kg Ha^{-1}	The amount of K_2O applied in per hectare basis
NRate	Numeric	Kg Ha^{-1}	The amount of N applied in per hectare basis
PRate	Numeric	Kg Ha^{-1}	The amount of P_2O_5 applied in per hectare basis
PreviousCrop	Categorical	-	Crop planted prior to the rice cropping event
SeedDateDeviation	Numeric	day	The number of days between the planting date and November 1st
SeedMethod	Categorical	-	Method used for seed implementation
SeedRate	Numeric	Kg Ha^{-1}	Amount of seed used in per hectare basis
TillageMethod	Categorical	-	Method used for land preparation
TillageTiming	Categorical	-	In which season the tillage is performed
Variety	Categorical	-	The name of rice cultivar planted in the field
Weed	Categorical	-	The severity of weed infestation, determined by the cooperative agronomists
WeedControl	Categorical	-	The use of Clearfield® rice and weed control package. Only present in conventional variety-planting fields
Yield	Numeric	Kg Ha^{-1}	The amount of dried and cleaned rice paddle harvested, per hectare basis

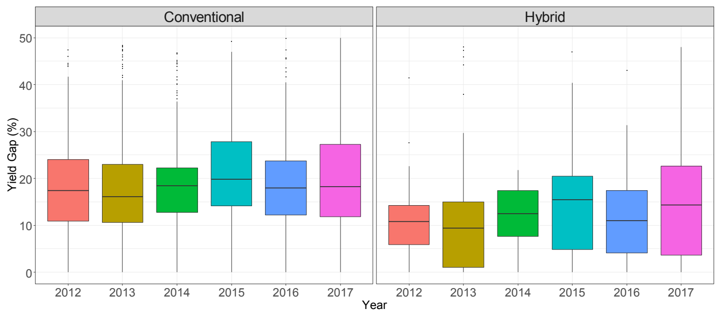
Methods

1. Dataset was split into hybrid and conventional variety fields.
2. Yield gap was defined as $\frac{EY_f - FY}{EY_f} * 100$ (%) where EY_f is mean yield of top decile.
3. Data cleaning and imputation was performed, and 2 random forest models were created using randomforest package.
4. Model was interpreted using iml package to obtain variable importance and accumulated local effects (ALE) plots.
5. As field potential was a crucial factor, a decision tree was created for conventional fields to summarize management practices for increasing yields in low-potential fields.

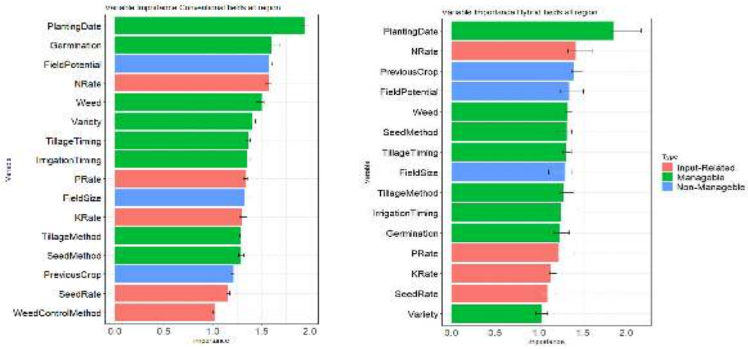
Summary of yield, production area, and management characteristics for three major rice regions in Uruguay.

Region	Yield (Kg ha^{-1})	Field size (Ha)	Total Area (K ha)	Main Variety	N (Kg ha^{-1})	P_2O_5 (Kg ha^{-1})	K_2O (Kg ha^{-1})	Tillage Timing	Previous Crop
East	8491±1417	117±97	228	El Paso 144 (36%) Tacuari (34%)	72.6±20.5	48.2±12.9	26.8±24.8	Sping (50%)	Improved Pasture (37%) Rice, 1st Year (25%)
Central	8270±1377	77±65	75.9	Olimar (30%) Inov (26%)	71.6±23.3	46±9.2	36.1±23.2	Sping (50%)	Raw Pasture (36%) Rice 1st Year (24%)
North	8380±1442	115±107	110	Olimar (71%) El Paso 144 (15%)	68±16.6	41.7±11.8	17.5±23.4	Fall/Winter (76%)	Rice, 1st Year (34%) Rice, 2nd year (18%)

Yield gap in conventional and hybrid variety fields was 20% and 13%, respectively. Seasonal variation affected yield gap variability and mean.



Early planting was most influential among other factors at field-level, regardless of the type of rice variety planted.

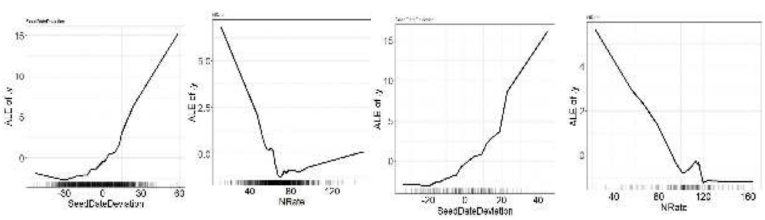


1. Early planting contributes to ~12% of yield gap reduction across fields
2. N fertilization reduces yield gap, while optimum N rate varies across variety types
3. Planting data, field potential, N rate, and weed infestation are common influential factors
4. Germination is important in conventional fields while previous crop is important in hybrid fields

Random forest models for hybrid and conventional variety fields

Accumulated local effects for conventional fields

Accumulated local effects for hybrid fields



Highlights

- Data-driven approach to narrow yield gaps, improving whole system productivity
- Random forest model was flexible tool for uncovering relationships in complex field-level data and identifying key factors contributing to yield gaps
- The information can be used to set future research targets/goals

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How much is the Potential, Actual and Yield Gap of Irrigated Rice in Brazil?

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ABSTRACT

The yield potential (Yp) is the yield of a cultivar that grows without nutrient limitations, biotic stresses (weeds, insects and diseases) and water. This study aims to identify the yield potential and gap for irrigated rice in Brazil. The yield potential (Yp) was calculated using the ORYZA v3 model, according to the GYGA methodology. The Yp for irrigated rice in Brazil was 14.8 t ha^{-1}, the current average actual yield was 7.7 t ha^{-1} and the yield gap (Yg) was 49% of Yp or 7.1 t ha^{-1} (Figure 2). In RS, the yield potential ranged from 15.6 to 14.6 t ha^{-1}. The average yields between regions were similar, ranging from 7.0 to 8.5 t ha^{-1}, with the largest and smallest Yg found ranging from 51 to 45% of Yp.

Key words: Global Yield Gap Atlas, Yield potential, *Oryza sativa* L., food security.

1. Introduction

Brazil is the ninth largest rice producer in the world, in the average of five last years (2014-2018), Brazilian rice production was 12 Mt (USDA, 2019), with the southern region (Paraná, Rio Grande do Sul and Santa Catarina) responsible for around 80% of Brazilian production and the state of Rio Grande do Sul (RS) the largest producer, with 69 of national production (CONAB, 2019). In terms of area, 1.1 million hectares of rice are cultivated annually in the state of Rio Grande do Sul (CONAB, 2019), and rice is among the crops that represent most of the gross domestic product generated by the agricultural sector in this state.

The yield potential (Yp) is the yield of a cultivar that grows without nutrient limitations, biotic stresses (weeds, insects and diseases) and water, i.e. the growth rate of the plant or crop is determined by solar radiation intercepted by the canopy, temperature, atmospheric CO2 and genetic characteristics (EVANS, 1993; VAN ITTERSUM & RABBINGE, 1997). The yield gap (Yg), the yield gap, is the difference between Yp and average farmer productivity, also called as yield actual (Ya) (LOBELL et al., 2009). In this sense, a new approach has been developed globally from a project called the

"Global Yield Gap Atlas" (GYGA - www.yieldgap.org), created due to concerns about the food and nutritional security of the population worldwide. In Brazil, studies on yield potential and gaps are still incipient, having been performed for sugarcane and corn crops (MONTEIRO & SENTELHAS, 2014; GLOBAL YIELD GAP ATLAS, 2016).

Currently, Brazil is part of the GYGA project together with more than 54 countries, and has been represented (since 2015) by the FieldCrops Team of the Federal University of Santa Maria in the state of RS. Previous research has indicated that southern Brazil, especially the state of Rio Grande do Sul, could become a future world barn of irrigated rice. RS has the potential to become a grain barn because it produces irrigated rice in an area that receives abundant solar radiation (21 MJ m-2 day-1 - daily average during the harvest - September to March -), which is equal to or larger than all existing granaries in the world.

Thus, this study aims to identify the yield potential and gap for irrigated rice in Brazil.

2. Material and Methods

The ORYZA v3 model, which is a process based dynamic ecophysiological model (VAN WART et al., 2015), was used to estimate the Yp. This model uses solar radiation as the main environmental forcing for the daily calculation of dry matter accumulation, and the minimum and maximum temperature as the basis of the development rate calculation (BOUMAN et al., 2004). The ORYZA model was the rice crop simulation model of the International Rice Research Institute (IRRI) in the Philippines and the model for Yp estimation in GYGA rice yield gap studies.

ORYZA simulates irrigated rice growth and development in situations of potential production, water limitation and nitrogen limitation (BOUMAN & VAN LAAR, 2006), the model has already been calibrated for upland rice cultivation and lowlands in irrigated rice in Brazil. To make the potential estimates, we selected the areas that represent the largest production of irrigated rice in Brazil, according to GYGA methodology (GYGA, 2019). The selected areas covered the states of Rio Grande do Sul, which is the largest producer in Brazil (1.1 million ha) representing 78% national production, and Santa Catarina (Figure 1).

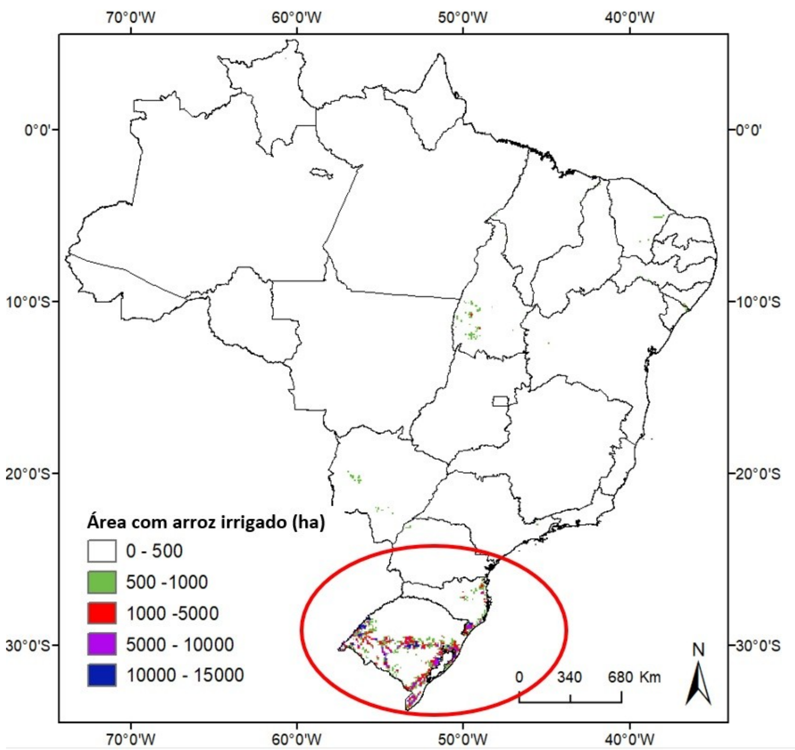

Figure 1. Production area of irrigated rice in Brazil. The red circle indicates the states (Rio Grande do Sul and Santa Catarina) with the largest representative's areas in irrigated rice production and which were selected for estimates of potential, current and productivity gap in Brazil.

Data on irrigated rice harvested area were obtained from IBGE. We used SPAM2005 (http://mapspam.info) to distinguish irrigated and rainfed areas. Daily weather data for the period from 2009 to 2018 were collected at INMET's automatic and conventional stations. The current average yield was obtained from data collected by IBGE during 2013-2018.

3. Results

It was identified that, on average, the yield potential for irrigated rice in Brazil was 14.8 t ha^{-1}, the current average actual yield was 7.7 t ha^{-1} and the yield gap was 49% of Yp or 7.1 t ha^{-1} (Figure 2). In RS, the yield potential ranged from 15.6 to 14.6 t ha^{-1}. The average yields between regions were similar, ranging from 7.0 to 8.5 t ha^{-1}, with the largest and smallest yield gap found ranging from 51 to 45% of Yp in the Coastal Plain and West Border, respectively (Figure 3).

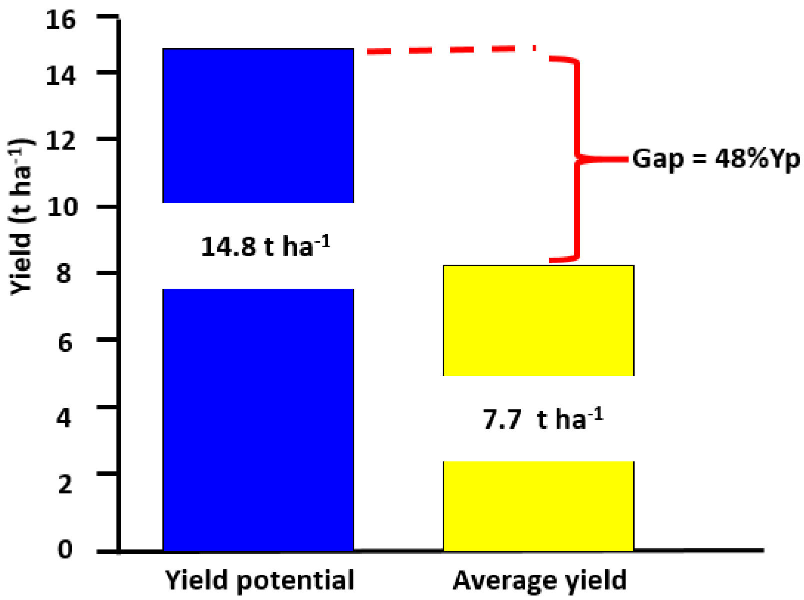

Figure 2. Average yield potential (Yp), Yield actual (Ya) and yield gap (Yg) for irrigated rice in Brazil. Estimates were made according to the GYGA methodology and the results are available at www.yieldgap.org.

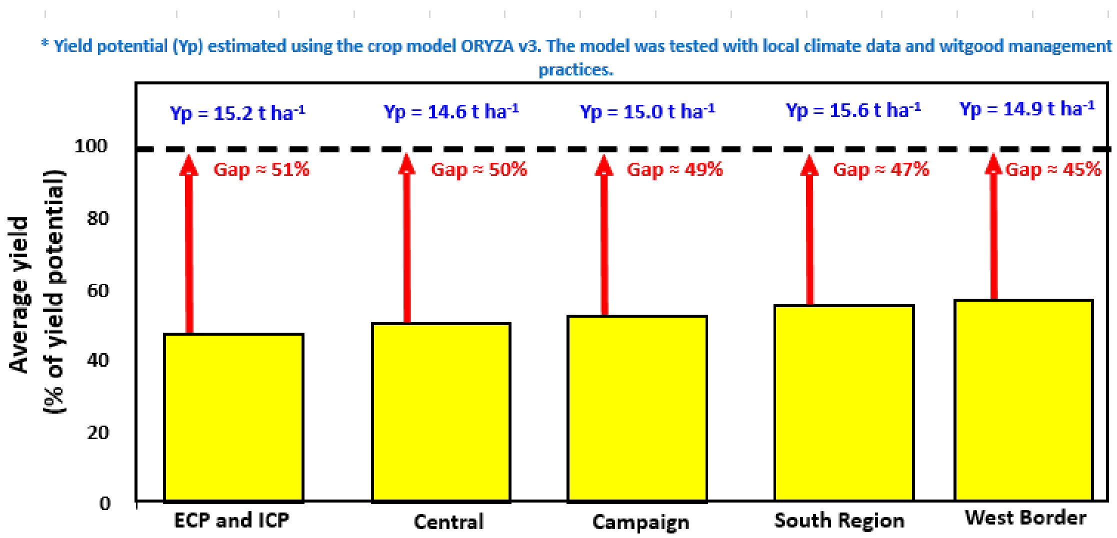

Figure 3. Average yield potential (Yp), Actual yield (Ya) and yield gap (Yg) for irrigated rice in different rice growing regions of Rio Grande do Sul.

4. Discussion

The results founded in this study shows that the West Border followed by the South Zone are the regions that are managing more efficiently their areas, which reflected in a smaller yield gap when compared to other regions of RS.

From a world point of view, the Lp found in Brazil, especially in RS, is similar to that found in Uruguay (Lp = 43%), is large when compared to the United States (Lp = 33%) and China (Lp = 27%).), but it becomes small when compared to Africa (Lp = 60%), which shows the importance of continuing to improve rice crop management in pursuit of increased productivity without expanding areas for sustainability and preservation. biodiversity, unlike in some countries of the African continent, such as Burkina Faso, Ghana and Egypt. All these results are available on the GYGA - www.yieldgap.org platform.

Conclusions

The yield potential (Yp) for irrigated rice in Brazil was 14.8 t ha^{-1}, the current average actual yield was 7.7 t ha^{-1} and the yield gap (Yg) was 49% of Yp or 7.1 t ha^{-1} (Figure 2). In RS, the yield potential ranged from 15.6 to 14.6 t ha^{-1}. The average yields between regions were similar, ranging from 7.0 to 8.5 t ha^{-1}, with the largest and smallest Yg found ranging from 51 to 45% of Yp.

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Yield potential of rice in Southern Brazil lowlands

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ABSTRACT

Most of the studies involving yield potential (Yp) of modern rice varieties were conducted in tropical conditions of Asia, and little is known about the rice yield potential in subtropical conditions of Brazil, the biggest rice producer country out of Asia. Playing a key role in the world rice production, there is a need to estimate how much rice Brazil can potentially produce and contribute with the future global rice demand. This study provides estimations of yield potential in southern Brazil by using the SimulArroz v1.1 model. The SimulArroz model was calibrated and validated with independent data in Rio Grande do Sul State. Using 33 years of weather data grid, downscaled to 0.25° x 0.25° resolution, maps of yield potential across the lowland rice production area of the State and sowing window were drawn. Yield potential ranged from less than 6 t ha^{-1} to over 14 t ha^{-1}. The boundary sowing date to avoid yield losses is 07 Nov in the average of the State, indicating that sowing date might be one of the major causes of the rice yield gap in Brazil. Another practical implication of the results of this study is that farmers can adjust the fertilizer rate to improve the nitrogen use efficiency according to the yield potential of the region and the sowing date.

Key words: *Oryza sativa*, crop Model, ORYZA, SimulArroz.

1. Introduction

Rice (Oryza sativa L.) plays a strategic role in Brazilian economy and society, as the country is the largest world rice producer outside Asia. About 70% of the Brazilian rice is produced in the Subtropics of the Rio Grande do Sul (RS) State, as flooded rice in 1.1 million hectares of lowlands. The potential for RS to be another major breadbasket is because most of the existing irrigated rice area in RS receives abundant solar radiation during the reproductive phase (c. 18 MJ m^{-2} day^{-1} – average from Dec to Apr), which is equal to or greater than all existing breadbaskets (Bourne, 2014; Cassman, 1999).

Yield potential (Yp) of any crop is defined as the yield of an adapted variety that develops under excellent conditions, without any stress or limitation caused by water, nutrients, weeds, pests and diseases (Evans, 1993). Under these conditions, the growth rate and yield are defined only by the intercepted solar radiation, temperature, atmospheric CO2 and genetics (Evans, 1993; van Ittersum et al., 1997). The 12-14 t ha^{-1} reported in well conducted experiments (Ribas et al., 2017) may be below Yp, as in field experiments it is difficult to keep the crop free of the biotic or abiotic stresses. On the other hand, Yp can be achieved by using crop simulation models (van Ittersum et al., 2013). The SimulArroz model was developed to simulate irrigated rice yield potential in subtropical rice systems of Brazil and has been calibrated and validated for many rice varieties grown in RS (Ribas et al., 2017).

Although farmers and agronomists know the effect of the sowing date on rice yield, their knowledge is based on experience or on field trials that do not capture the effect of the whole range of sowing dates in different regions of the subtropical lowland rice production area in Brazil. In order to fill the lack of information and to quantify the variability of yield potential in the Brazilian subtropical lowland environment, the objective of this study was to estimate rice yield potential on a high-resolution grid for different sowing dates in the Brazilian subtropics.

2. Material and Methods

Since 90% of all rice produced in Brazil is cultivated in irrigated lowlands, and the RS is responsible for 70% of the national production, this study comprised the majority of the Brazilian production area (Figure 1). According to van Wart et al. (2013), a coverage of 50% of the production area is enough to obtain a robust estimate of the yield potential on a national scale.

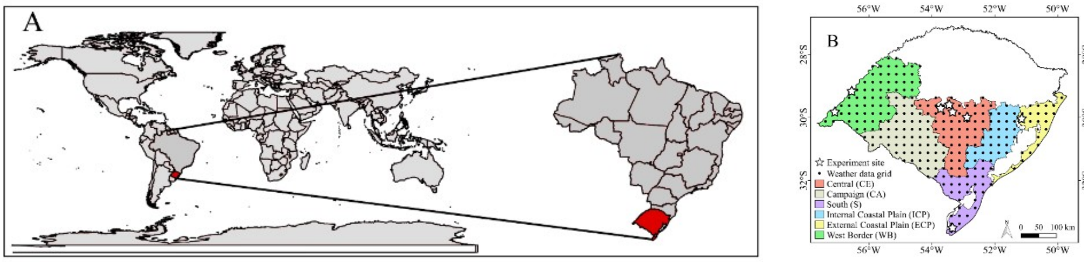

Figure 1. (A) Geographical location of the study area; (B) Regions of the Rio Grande do Sul state where rice is produced (1.1 million hectares of lowlands) and the weather data grid;

SimulArroz is a process-based model that calculates phenology, dry matter (DM) production and yield potential for irrigated rice on a daily time step. To run the model, users need to input daily weather data of maximum and minimum temperature, and solar radiation (MJ m^{-2} day^{-1}), and crop parameters, such as cultivar or maturity group, sowing or emergence date, plant density (pl m^{-2}), number of simulated years, technological level and atmospheric CO_2 concentration. Version 1.1 of the SimulArroz model available for free download at www.ufsm.br/simularroz was used in this study. To have a robust estimate of the yield potential that captures the spatial and time discrepancy of South Brazil, the present study used daily weather data (solar radiation, minimum and maximum temperature) of a 0.25° x 0.25° grid (Figure 1B) during the period from 1980 to 2013, which were collected from the Daily gridded meteorological variables in Brazil (1980-2013) (Xavier et al., 2016).

The cultivar IRGA 424 RI was used to simulate the Yp across the state, which is the highest yielding and most sown cultivar in South Brazil. The sowing date is one of the farming managements practices that has a strategic role for obtaining high and stable yields, because it allows to grow plants to avoid adverse climatic variables during the critical phase and coincide with the favorable ones (Stansel, 1975). The sowing dates were set on the 1st and 15th day of the month, from September to January, aiming to capture the entire range of the commonly used sowing dates. The plant density was set at 200 pl m^{-2} and the atmospheric CO_2 concentration was 400 ppm. The technological level was set to potential, meaning that simulated yield potential was only a function of solar radiation and temperature. The model was run at 10 sowing dates, 33 years and 257 grid points, totaling 84810 runs. The software QGIS v. 2.8.9 was used to interpolate the yield potential on the data grid using the Inverse Distance Weighting (IDW) method, and to elaborate maps for each sowing date. Random field experiments data were collected to evaluate the performance of the model in simulating yield across different years and sowing dates.

3. Results and Discussion

The average rice yield potential (Yp) for RS, estimated by the SimulArroz model, ranged from less than 6 t ha^{-1} to greater than 14 t ha^{-1} according to the regions and sowing dates (Figure 2). Except for the sowing dates in January, the WB always presented the highest values of yield potential, and the north part of ECP, the lowest yield potential region. The differences on yield potential between WB and ECP regions can be explained by the environment, as the WB region has climatic conditions more favorable to rice growth and development (temperature and solar radiation) when compared to northern ECP. According to Huang et al. (2016) biomass production is positively related to intercepted solar radiation, and yield is positively related to biomass production. In other words, the higher the intercepted solar radiation, the higher yields can be achieved, and the lower yield potential estimated in eastern RS might be related to lower solar radiation. Furthermore, low temperatures can also reduce rice yield in sowing dates near the boundaries of the sowing window (Sept and Dec-Jan), which occur more frequently in CA and S regions.

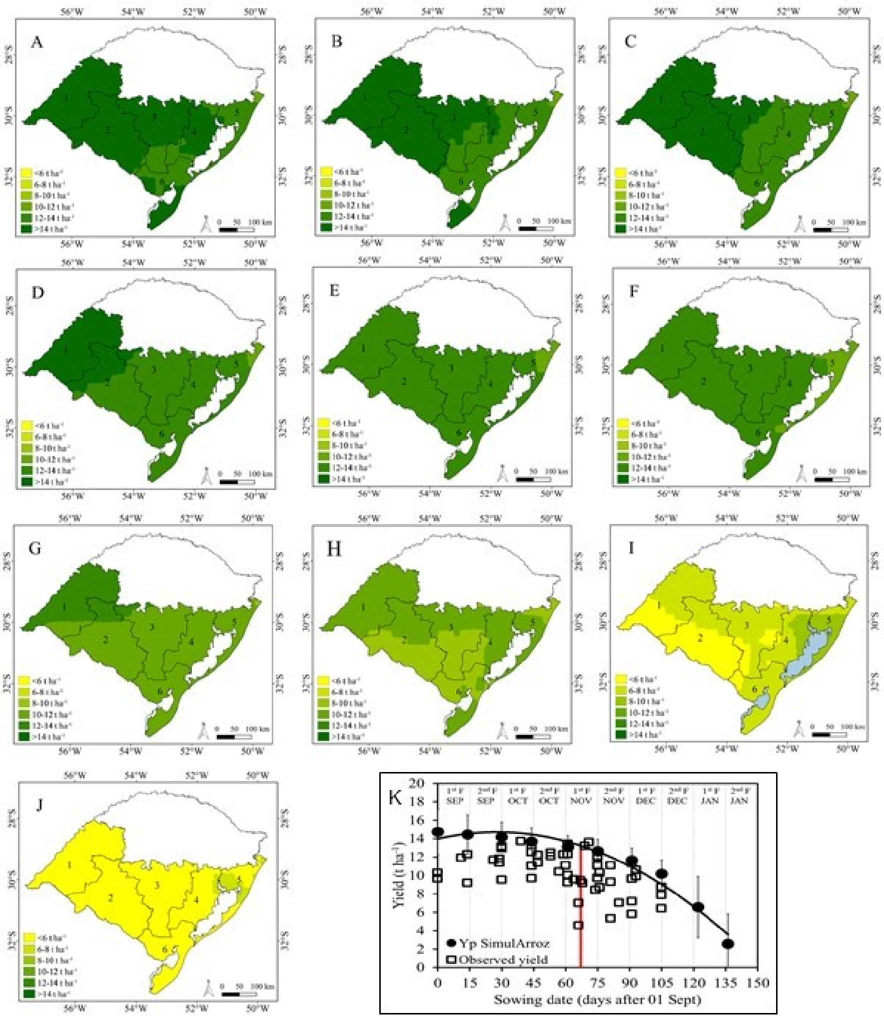

Figure 4. Yield potential of rice on different sowing dates in lowlands of Rio Grande do Sul State, Brazil, with sowing dates on (A) 01 Sept; (B) 15 Sept; (C) 01 Oct; (D) 15 Oct; (E) 01 Nov; (F) 15 Nov; (G) 01 Dec; (H) 15 Dec; (I) 01 Jan; (J) 15 Jan; (K) Rice yield as a function of sowing date (expressed as days after 01 Sept) in Brazilian subtropical lowlands. Solid circles represent the average yield potential simulated with the SimulArroz model (n = 84810). Squares represent the observed yields on field experiments and farm fields (n = 60). The black curve represents the fitted trend line for yield potential. The red vertical line represents the sowing date where the yield potential penalty becomes higher than 0.5% day-1 (i.e. *P <0.05). Bars indicate the standard deviation for yield potential.

The Yp of rice found for Brazil is superior to the Yp of Bangladesh (11.7 t ha^{-1}) and Philippines (6.1-8.7 t ha^{-1}), as reported by Timsina et al. (2016) and Silva et al. (2016), respectively. This difference can be explained by higher solar radiation and longer photoperiod during flowering and grain filling phases in the Brazilian subtropical climate compared to the tropical climate of South and Southeast Asia. Espe et al. (2016) estimated similar yield potential (8.2-14.5 t ha^{-1}) for temperate conditions of Southern United States, highlighting that environments out of tropical conditions have higher rice yield potential, but also have higher risks of production loss due to cold damage. Besides the different methods of Yp estimates, subtropical rice production regions, near to the Latitude of 30°, presents higher Yp when compared to lower latitudes, as near to the tropics there is less solar radiation available during the growing season, and temperate regions presents higher risk of crop damage due to low temperatures.

The response of yield potential estimated by the SimulArroz model as a function of sowing dates (Figure 2K) indicates that the yield potential penalty starts to become significant (0.5% day^{-1}) at 67 days after 01 Sept, which means that the boundary date to avoid yield potential losses is 07 Nov, and the penalty increases sharply with the delay in the sowing date. As the best environmental conditions (i.e. solar radiation and temperature) for rice crops in south hemisphere subtropics occur during the summer season (Dec-Jan-Feb), sowing dates before 07 Nov match the critical developmental stages of rice (i.e. reproductive and grain filling stages) with the period with higher availability of solar radiation, which is directly related to rice yield and avoid yield losses caused by extreme temperatures during flowering. The Standard deviation of yield potential across the different sowing dates ranged from 9% on 01 Nov to over 126% on 15 Jan (Figure 2K). The lower standard deviation in the sowing between 01 Oct and 01 Dec means that the yield potential is more stable over the historical data.

Conclusions

This study provides robust estimates of yield potential for the Brazilian subtropical irrigated rice in different sowing dates, based on a multi-year high resolution weather data. The results have practical applications for farmers and consultants, helping them in management decisions and to guide them in adjusting the amount of inputs (e.g. fertilizers and pest chemicals) according to the yield potential for the region and sowing date. However, future studies need to be performed for better understanding of nitrogen dynamics across sowing dates. Our results can also be used in future studies about rice yield gaps in Brazil, as the Country's average yield is far from the yield potential. With higher yield potential than tropical environments, Brazil can contribute to future rice demands and contribute to world's food security.

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Introduction

- About 70% of the Brazilian rice is produced in the Subtropics of the Rio Grande do Sul (RS) State, as flooded rice in 1.1 million hectares of lowlands. The potential for RS to be another major breadbasket is because most of the existing irrigated rice area in RS receives abundant solar radiation during the reproductive phase (c. 18 MJ m-2 day-1 – average from Dec to Apr), which is equal to or greater than all existing breadbaskets (Bourne, 2014; Cassman, 1999).
- Yield potential (Yp) of any crop is defined as the yield of an adapted variety that develops under excellent conditions, without any stress or limitation caused by water, nutrients, weeds, pests and diseases (Evans, 1993).
- The SimulArroz model was developed to simulate irrigated rice yield potential in subtropical rice systems of Brazil and has been calibrated and validated for many rice varieties grown in RS (Ribas et al., 2017).

Objective

- The objective of this study was to estimate rice yield potential on a high-resolution grid for different sowing dates in the Brazilian subtropics

Material and Methods

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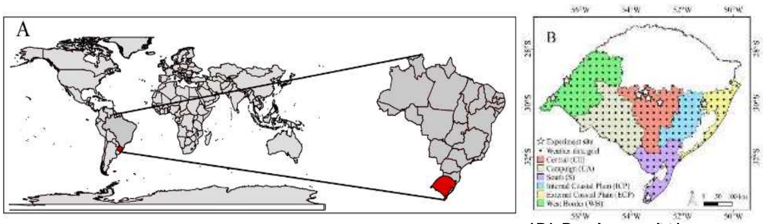

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- Version 1.1 of the SimulArroz model available for free download at www.ufsm.br/simularroz was used in this study.

Results

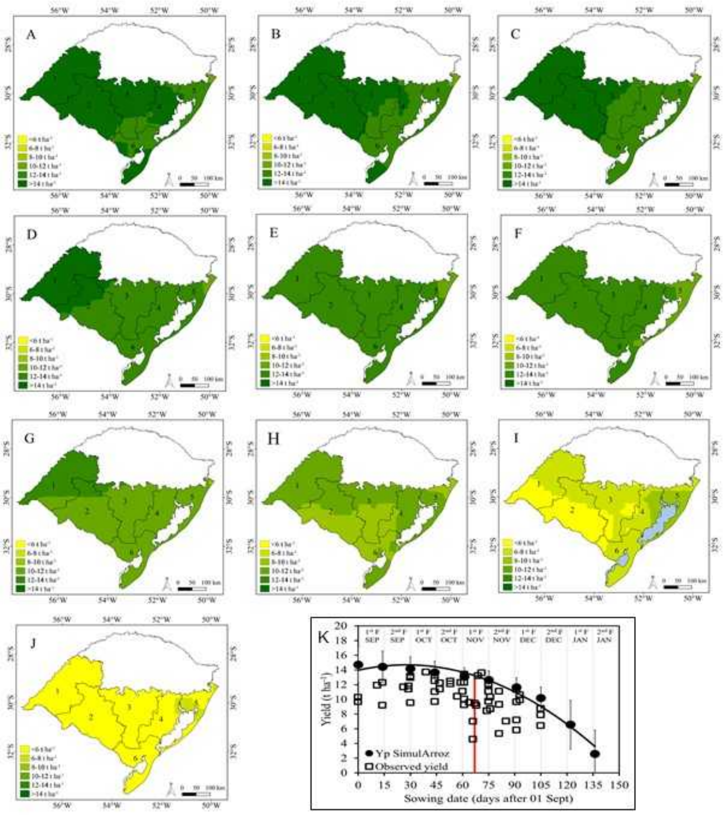

Figure 4. Yield potential of rice on different sowing dates in lowlands of Rio Grande do Sul State, Brazil, with sowing dates on (A) 01 Sept; (B) 15 Sept; (C) 01 Oct; (D) 15 Oct; (E) 01 Nov; (F) 15 Nov; (G) 01 Dec; (H) 15 Dec; (I) 01 Jan; (J) 15 Jan; (K) Rice yield as a function of sowing date (expressed as days after 01 Sept) in Brazilian subtropical lowlands. Solid circles represent the average yield potential simulated with the SimulArroz model (n = 84810). Squares represent the observed yields on field experiments and farm fields (n = 60). The black curve represents the fitted trend line for yield potential. The red vertical line represents the sowing date where the yield potential penalty becomes higher than 0.5% day-1 (i.e. *P <0.05). Bars indicate the standard deviation for yield potential.

Conclusions

- This study provides robust estimates of yield potential for the Brazilian subtropical irrigated rice in different sowing dates, based on a multi-year high resolution weather data. The results have practical applications for farmers and consultants, helping them in management decisions and to guide them in adjusting the amount of inputs (e.g. fertilizers and pest chemicals) according to the yield potential for the region and sowing date.
- Our results can also be used in future studies about rice yield gaps in Brazil, as the Country's average yield is far from the yield potential. With higher yield potential than tropical environments, Brazil can contribute to future rice demands and contribute to world's food security.

SELECTIVITY OF PROFOXYDIM AND METAMIFOP ON RICE VARIETIES AT THE EASTERN REGION OF URUGUAY

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ABSTRACT

Herbicides that inhibitor acetyl-coenzyme A carboxylase (ACCase) had started to be used to control herbicide-resistant barnyardgrass (*Echinochloa crusgalli*) in Uruguay. It is worthy to assess selectivity of profoxydim and metamifop on new varieties of rice recently released. A field experiment was conducted at the Experimental Unit of Paso de la Laguna in 2016-17 and 2017-18. In trial E1, rice plants were at two to four leaf-stage, and in trial E2, half of them were at tillering-stage when sprayed. Treatments evaluated were a factorial combination of variety and herbicide treatment. Two *indica* subtype (INIA Olimar and INIA Merín) and one tropical *japonica* subtype (Parao) were used. Herbicide treatments included a check without herbicide, 75 and 150 g ha^{-1} of metamifop, and 100 and 200 g ha^{-1} of profoxydim for E1, instead 100 and 200 g ha^{-1} of metamifop, 175 and 350 g ha^{-1} of profoxydim plus a check without herbicide for E2. Treatments were under a CRBD with three replications. A transient stunted growth in INIA Olimar was detected just in 2017-18 due to profoxydim but there was no rice yield reduction for any of the varieties evaluated neither in trial E1 nor in trial E2.

Key words: rice subtype, variety, ACCase inhibitor, weather conditions, herbicide injury

1. Introduction

Herbicides, inhibitors of acetyl-coenzyme A carboxylase (ACCase), like cyhalofop-butyl and metamifop of the aryloxyphenoxypropionate (AOPP), and profoxydim of the cyclohexanediones (CHD) had been used to control herbicide-resistant barnyardgrass. Since 2004, the percentage of *indica* subtype rice decrease from 80 to 65%, instead tropical *japonica* subtype increased slightly up to 20%. Most of the remaining acreage was seeded with temperate *japonica* subtype rice (Molina, et al., 2019). At field-scale in 2001, profoxydim injured severely El Paso 144 (*indica* subtype) (Deambrosi and Bonilla, 2002). When tested at small plot-scale trials in 2002, INIA Olimar (*indica* subtype) lost yield at the higher rate of profoxydim, while INIA Tacuarí (tropical *japonica* subtype) was not affected (Saldain and Deambrosi, 2003). In other trials, most of the plants of INIA Olimar died, showing less tolerance to profoxydim than EL Paso 144 and INIA Tacuarí (Figure 1, Com. Pers. Deambrosi and Saldain, 2004). Plants of CL212 (*indica* subtype), a blast disease (*Pyricularia oryzae*) resistant variety, died particularly when there were at four leaf-stage on postemergence spraying (Figure 2, Saldain and Sosa, 2017). This experiment was aimed to determine the selectivity of profoxydim and metamifop on high productivity and blast disease resistant new rice varieties like Parao (tropical *japonica* subtype) and INIA Merín (*indica* subtype).

2. Material and Methods

A field experiment was conducted during 2016-2017 and 2017-2018 rice seasons at the Experimental Unit of Paso de la Laguna (UEPL), Treinta y Tres, Uruguay. In the trial E1 herbicide treatments were applied on early postemergence at two to four-leaf stage of rice plants, while in trial E2, herbicide spraying was done when half of them was at tillering-stage. Treatments assessed came

from a factorial (Table 1) and they were layout under a CRBD with three replications. In Table 2, dates of main field activities are showed for both trials. Statistical analysis was done using Mixed procedure of SAS (Statistical Analysis System v9.4) and Dunnett test was used to pairwise comparisons between
no herbicide treatment (check) and different levels of the factor herbicide treatment.

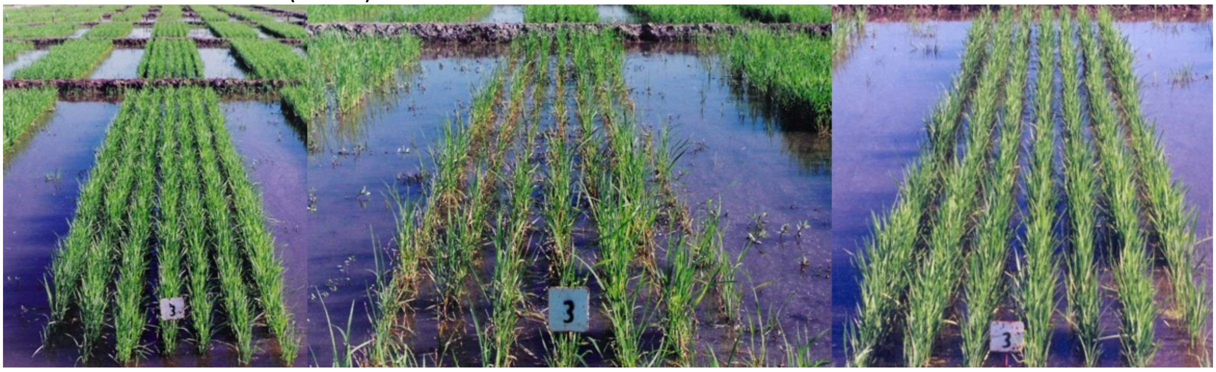

Figure 1. Rice injury observed when 140 g ha^{-1} of profoxydim was applied on rice plants at two to four leaf-stage. Left: El Paso 144 (*indica* subtype), Center: INIA Olimar (*indica* subtype) and Right: INIA Tacuarí (tropical *japonica* subtype). UEPL, 2003-2004.

Figure 2. Injury of profoxydim on CL212. Left: Differential tolerance between plants at tillering-stage and at leaf-stage when treated with 190 g ha^{-1} of profoxydim. Right: Central plot had profoxydim, and side plots were sprayed with 80 g ha^{-1} of metamifop. Río Branco, 2016-17.

Table 1. Varieties and herbicide treatments studied. UEPL, 2016-17 and 2017-18.

Factor		Dose, g ha^{-1}		Herbicide		Coadyuvant	
Variety	Herbicide	Trial E1	Trial E2	Product	g l^{-1}	Product	Dose
INIA Olimar	no herbicide	0	0	no	no	no	no
INIA Merín	metamifop	75 and 150	100 and 200	Metamifox	100	GRÜN ÖL	500 ml ha^{-1}
Parao	profoxydim	100 and 200	175 and 350	Aura®	200	DASH	0,5% v/v

Weed that survive were removed by hands doing three passes in both trials

Table 2. Field operations in rice selectivity experiment. UEPL, 2016-17 and 2017-18.

Field practices	Trial E1	Trial E2
Glyphosate on fallow land	3,5 l/ha de Glifoweed + 30 g/ha de Cerio	
Date of seeding rice	30-set-16, 11-oct-17	07-nov-16, 10-nov-17
Seeding density (viables seeds m^{-2})	485 in 2016 and 400 in 2017	
Date of spraying herbicide treatments	31-oct-16, 11-nov-17	07-dic-16, 13-dic-17
Flushing date	It was unnecessary	
Flooding date	14-nov-16, 23-nov-17	09-dic-16, 18-dic-17

3. Results and Discussion

When cold and cloudy days occurred simultaneously, severe injury of profoxydim was observed in 2001, 2002, and 2003. Those are a baseline data to contextualize the results obtained (Table 3). In both trials, no yield reduction was detected for any treatment (Tables 4 and 5). The stunted growth of INIA Olimar was transient and due to profoxydim on trial E1 in 2017. Although days were colder around spraying date than the baseline data, there is no severe injury. At the same time, those days were also sunnier, apparently preventing permanent injury and rice yield lost.

Table 3. Weather variables average ± standard deviation over 3 and 5 days around spraying date at the Experimental Unit of Paso de la Laguna, 2001-2003, 2016 and 2017.

Year of seeding	Temperatures (ºC) average	minimum*	Thermal amplitude, ºC	Relative heliophany, (%)	Rainfall event mm day^{-1}
3 days (± 1 day around spraying date)					
2001(1)	19.8 ± 2.0	10.6 ± 3.1	13.4 ± 4.7	45 ± 28	7.0
2002(2)	21.3 ± 0.8	16.2 ± 0.5	7.4 ± 2.0	38 ± 28	19.2, 1.8
2003(3)	20.4 ± 0.7	10.7 ± 1.7	12.7 ± 0.9	45 ± 22	0.5
2016 (E1)	19.8 ± 2.0	10.6 ± 3.1	13.4 ± 4.7	53 ± 40	40.3
2017 (E1)	17.2 ± 3.3	3.2 ± 3.1	20.3 ± 2.4	79 ± 1	-
2016 (E2)	21.3 ± 2.4	11.3 ± 2.8	14.9 ± 1.4	78 ± 14	-
2017 (E2)	22.5 ± 3.7	9.3 ± 7.7	18.7 ± 3.1	70 ± 12	-
5 days (± 2 days around spraying date)					
2001(1)	17.3 ± 3.8	9.1 ± 4.9	13.1 ± 4.3	48 ± 31	72.4
2002(2)	21.1 ± 1.4	14.6 ± 2.4	8.5 ± 2.1	37 ± 22	0.7
2003(3)	20.5 ± 0.6	10.6 ± 1.3	13.4 ± 1.5	61 ± 27	-
2016 (E1)	17.3 ± 3.8	9.1 ± 4.9	13.1 ± 4.3	61 ± 31	-
2017 (E1)	16.7 ± 2.4	4.0 ± 2.8	18.2 ± 3.8	73 ± 16	-
2016 (E2)	20.6 ± 3.4	9.4 ± 5.3	16.0 ± 2.9	78 ± 11	-
2017 (E2)	22.3 ± 3.5	9.1 ± 5.6	18.0 ± 3.8	75 ± 11	-

(E1)=Trial E1, (E2)=Trial E2, *=temperature minimum above 5 cm on turf, (1)=El Paso 144 severly injured (Deambrosi and Bonilla, 2002), (2)=INIA Olimar severly injured at the highest dose of profoxydim used (Deambrosi and Saldain, 2003), (3)=Plants of INIA Olimar dead by 140 g ha^{-1} of profoxydim at figure 1 (Com Pers. Deambrosi and Saldain, 2004)

4. Conclusions

Field study of herbicide selectivity needs to be repeated many years and locations to identify appropriately weather conditions promoting herbicide injury and its association with rice subtype and variety on productivity.

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Table 4. Effect of the interaction among year*variety*herbicide treatment on selected variables and rice yield adjusted by milling quality in trial E1 at UEPL.

Year of seeding	Variety	Herbicide treatment	Dose g ha^{-1}	Plants m^{-2}	Plant height, cm plant^{-1} 15 DAS	30 DAS	Flowering date	Panicles m^{-2}	1000-grains weight, g	Rice yield kg ha^{-1}
2016	INIA Olimar	No herbicide	0	178 a	12.0 a	31.1 a	30-ene. a	575 a	28.2 a	10205 a
		metamifop	75	186 a	13.0 a	32.5 a	28-ene. a	497 a	28.2 a	10902 a
		metamifop	150	140 a	12.4 a	32.7 a	29-ene. a	562 a	28.4 a	9755 a
		profoxidim	100	188 a	12.6 a	32.9 a	28-ene. a	523 a	28.7 a	10514 a
		profoxidim	200	170 a	11.8 a	32.0 a	30-ene. a	516 a	28.3 a	10729 a
	INIA Merín	No herbicide	0	178 a	12.4 a	32.8 a	3-feb. a	621 a	27.6 a	11735 a
		metamifop	75	191 a	11.4 a	30.7 a	4-feb. a	513 a	27.6 a	13069 a
		metamifop	150	208 a	11.7 a	29.9 a	4-feb. a	624 a	27.7 a	12431 a
		profoxidim	100	184 a	11.5 a	31.8 a	5-feb. a	637 a	28.1 a	12738 a
		profoxidim	200	180 a	10.8 a	27.6 b	5-feb. a	608 a	27.8 a	10824 a
	Parao	No herbicide	0	293 a	11.7 a	26.5 a	29-ene. a	611 a	28.7 a	12394 a
		metamifop	75	264 a	12.1 a	26.7 a	26-ene. b	464 a	28.8 a	10391 a
		metamifop	150	265 a	11.6 a	27.5 a	26-ene. b	552 a	28.7 a	10936 a
		profoxidim	100	253 a	12.3 a	28.5 a	28-ene. a	598 a	28.8 a	11114 a
		profoxidim	200	267 a	10.7 a	26.8 a	28-ene. a	618 a	28.9 a	11820 a
2017	INIA Olimar	No herbicide	0	187 a	20.5 a	47.3 a	29-ene. a	701 a	28.5 a	10416 a
		metamifop	75	223 a	20.5 a	46.7 a	30-ene. a	651 a	28.5 a	10546 a
		metamifop	150	203 a	20.2 a	48.9 a	29-ene. a	616 a	28.5 a	10770 a
		profoxidim	100	163 a	17.1 b	48.4 a	31-ene. a	553 a	29.0 a	9528 a
		profoxidim	200	157 a	16.9 b	48.0 a	2-feb. b	525 b	28.9 a	10415 a
	INIA Merín	No herbicide	0	215 a	15.9 a	45.2 a	9-feb. a	688 a	26.7 a	12508 a
		metamifop	75	195 a	16.1 a	42.8 a	8-feb. a	647 a	26.9 a	11167 a
		metamifop	150	198 a	16.4 a	44.5 a	8-feb. a	623 a	26.9 a	10768 a
		profoxidim	100	185 a	15.3 a	42.2 a	9-feb. a	610 a	26.7 a	10846 a
		profoxidim	200	231 a	15.8 a	42.4 a	9-feb. a	603 a	27.0 a	11366 a
	Parao	No herbicide	0	163 a	15.8 a	35.4 a	29-ene. a	492 a	27.0 a	9691 a
		metamifop	75	210 a	16.7 a	35.6 a	29-ene. a	538 a	27.8 a	10983 a
		metamifop	150	193 a	16.7 a	36.0 a	29-ene. a	521 a	27.8 a	11437 a
		profoxidim	100	233 a	15.7 a	36.0 a	29-ene. a	551 a	28.1 b	10678 a
		profoxidim	200	228 a	15.5 a	35.4 a	29-ene. a	529 a	27.4 a	10672 a
Dunnett$_{0,05}$				78	2.4	3.4	2 days	156	0.9	2363

DAS=days after spraying

Table 5. Effect of the interaction between variety*herbicide treatment on selected variables and rice yield (averaged over year) adjusted by milling quality in trial E2. UEPL in 2016-17 and 2017-18.

Variety	Herbicide Treatment	Dose g ha^{-1}	Tillers m^{-2}	Plant height, cm $plant^{-1}$ 15 DAS	30 DAS	Flowering date	Panicles m^{-2}	1000-grains weight, g	Rice yield kg ha^{-1}
INIA Olimar	No herbicide	0	747 a	39.6 a	64.0 a	15-feb. a	634 a	26,8 a	11375 a
	metamifop	100	732 a	41.8 a	64.3 a	16-feb. a	665 a	26,7 a	11757 a
	metamifop	200	730 a	40.6 a	65.3 a	17-feb. a	591 a	26,9 a	11371 a
	profoxidim	175	747 a	39.4 a	64.9 a	16-feb. a	693 a	26,9 a	11747 a
	profoxidim	350	757 a	39.4 a	63.8 a	17-feb. a	604 a	26,7 a	11690 a
INIA Merín	No herbicide	0	752 a	37.2 a	59.7 a	27-feb. a	634 a	26,8 a	10429 a
	metamifop	100	746 a	39.1 a	59.1 a	26-feb. a	626 a	27,1 a	12396 b
	metamifop	200	734 a	38.7 a	61.0 a	28-feb. a	578 a	26,9 a	10498 a
	profoxidim	175	732 a	38.7 a	62.7 b	27-feb. a	616 a	27,0 a	11224 a
	profoxidim	350	746 a	37.7 a	61.3 a	27-feb. a	701 a	26,9 a	11257 a
Parao	No herbicide	0	641 a	30.8 a	52.2 a	18-feb. a	593 a	26,8 a	11883 a
	metamifop	100	592 a	34.0 a	53.3 a	17-feb. a	542 a	24,9 b	11562 a
	metamifop	200	643 a	32.8 a	52.3 a	18-feb. a	569 a	25,3 b	12373 a
	profoxidim	175	613 a	32.6 a	53.7 a	19-feb. a	567 a	25,7 b	12294 a
	profoxidim	350	560 a	31.4 a	52.4 a	18-feb. a	601 a	25,9 b	12604 a
$Dunnett_{0,05}$			139	2.2	3.7	4.8	128	0.7	1123

DAS=days after spraying

SELECTIVITY OF PROFOXYDIM AND METAMIFOP ON RICE VARIETIES AT THE EASTERN REGION OF URUGUAY

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Introduction

Rice varietal difference was observed when 140 g ha^{-1} of profoxydim was applied on early postemergence at two to four leaf-stage rice plants (Figure 1, Com. Pers. Deambrosi and Saldain, 2004)

Figure 1. Left: El Paso 144 (*indica* subtype), Center: INIA Olimar (*indica* subtype), Right: INIA Tacuarí (tropical *japonica* subtype). UEPL, 2003-04

Differential herbicide behavior on CL212 (INIA Olimar//CFX-18/EL Paso 144) was observed but there was not yield difference detected between treatments (Figure 2, Saldain and Sosa, 2018).

Figure 2. Injury of profoxydim on CL212 rice plants at different stages. Left: Differential tolerance at tillering-stage and at four leaf-stage when sprayed. Right: Central plot was treated with 190 kg ha^{-1} of profoxydim, and side plots were sprayed with 80 g ha^{-1} of metamifop. Río Branco, 2016-17.

Objective

This experiment was aimed to determine selectivity of profoxydim and metamifop on high productivity and blast disease resistant recently released varieties, INIA Merín (*indica* subtype) and Parao (tropical japonica subtype).

Material and Methods

- Experimental Unit of Paso de la Laguna, latitude 33º 16’ 23’’ S and longitude 54º 10’ 24’’ W, Treinta y Tres, Uruguay

- A field experiment was conducted in 2016-17 and 2017-18 rice seasons. In trial E1 herbicides were applied with rice plants at two to four leaf-stage, and in trial E2, half of them at tillering-stage

- A factorial combination of rice variety and herbicide treatment factors and levels were assessed.

Variety	Herbicide	Dose, g ha^{-1}	
	Treatment	Trial E1	Trial E2
INIA Olimar	no herbicide	0	0
INIA Merín	metamifop	75 and 150	100 and 200
Parao	profoxydim	100 and 200	175 and 350

weed that survive were removed by hands in the whole trial

- Treatments were under a completely randomized block design with three replications. Statistical analysis was done using Proc Mixed (SAS Institute v9.4) and for pairwise separation between check and each level of herbicide treatment a Dunnett$_{0,05}$ test was used.

- Field operations

Field practices	Trial E1	Trial E2
Date of seeding rice	30-set-16, 11-oct-17	07-nov-16, 10-nov-17
Seeding density (viables seeds m^{-2})	485 in 2016 and 400 in 2017	
Date of spraying herbicide treatments	31-oct-16, 11-nov-17	07-dic-16, 13-dic-17
Flushing date	It was unnecessary	
Flooding date	14-nov-16, 23-nov-17	09-dic-16, 18-dic-17

Aura= 200 g l^{-1} of profoxydim, coadyuvant DASH added at 0.5% v/v
Metamifox= 100 g l-1 of metamifop, coadyuvant GRÜN ÖL added at 500 ml ha^{-1}

Results

Weather data (Table 1) and results obtained for trial E1 (Table 2) are shown. As any difference was detected significant among treatments for any variable at trial E2, data are not shown.

Table 1. Weather variables average ± standard deviation over 3 and 5 days at spraying date at UEPL, 2001-2003 (baseline), 2016 and 2017.

Year of seeding	Temperatures (ºC) average	minimum*	Thermal amplitude, ºC	Relative heliophany, (%)	Rainfall event mm day^{-1}
3 days (± 1 day around spraying date)					
2001(1)	19.8 ± 2.0	10.6 ± 3.1	13.4 ± 4.7	45 ± 28	7.0
2002(2)	21.3 ± 0.8	16.2 ± 0.5	7.4 ± 2.0	38 ± 28	19.2, 1.8
2003(3)	20.4 ± 0.7	10.7 ± 1.7	12.7 ± 0.9	45 ± 22	0.5
2016 (E1)	19.8 ± 2.0	10.6 ± 3.1	13.4 ± 4.7	53 ± 40	40.3
2017 (E1)	17.2 ± 3.3	3.2 ± 3.1	20.3 ± 2.4	79 ± 1	-
2016 (E2)	21.3 ± 2.4	11.3 ± 2.8	14.9 ± 1.4	78 ± 14	-
2017 (E2)	22.5 ± 3.7	9.3 ± 7.7	18.7 ± 3.1	70 ± 12	-
5 days (± 2 days around spraying date)					
2001(1)	17.3 ± 3.8	9.1 ± 4.9	13.1 ± 4.3	48 ± 31	72.4
2002(2)	21.1 ± 1.4	14.6 ± 2.4	8.5 ± 2.1	37 ± 22	0.7
2003(3)	20.5 ± 0.6	10.6 ± 1.3	13.4 ± 1.5	61 ± 27	-
2016 (E1)	17.3 ± 3.8	9.1 ± 4.9	13.1 ± 4.3	61 ± 31	-
2017 (E1)	16.7 ± 2.4	4.0 ± 2.8	18.2 ± 3.8	73 ± 16	-
2016 (E2)	20.6 ± 3.4	9.4 ± 5.3	16.0 ± 2.9	78 ± 11	-
2017 (E2)	22.3 ± 3.5	9.1 ± 5.6	18.0 ± 3.8	75 ± 11	-

Table 2. Interaction among year of seeding*variety*herbicide treatment at UEPL. Label DAS means days after spraying

Year of seeding	Variety	Herbicide treatment	Dose g ha^{-1}	Plant height, cm plant^{-1} 15 DAS	30 DAS	Flowering date	Panicles m^{-2}	Rice yield kg ha^{-1}
2016	INIA Olimar	No herbicide	0	12.0 a	31.1 a	30-ene. a	575 a	10205 a
		metamifop	75	13.0 a	32.5 a	28-ene. a	497 a	10902 a
		metamifop	150	12.4 a	32.7 a	29-ene. a	562 a	9755 a
		profoxidim	100	12.6 a	32.9 a	28-ene. a	523 a	10514 a
		profoxidim	200	11.8 a	32.0 a	30-ene. a	516 a	10729 a
	INIA Merín	No herbicide	0	12.4 a	32.8 a	3-feb. a	621 a	11735 a
		metamifop	75	11.4 a	30.7 a	4-feb. a	513 a	13069 a
		metamifop	150	11.7 a	29.9 a	4-feb. a	624 a	12431 a
		profoxidim	100	11.5 a	31.8 a	5-feb. a	637 a	12738 a
		profoxidim	200	10.8 a	27.6 b	5-feb. a	608 a	10824 a
	Parao	No herbicide	0	11.7 a	26.5 a	29-ene. a	611 a	12394 a
		metamifop	75	12.1 a	26.7 a	26-ene. b	464 a	10391 a
		metamifop	150	11.6 a	27.5 a	26-ene. b	552 a	10936 a
		profoxidim	100	12.3 a	28.5 a	28-ene. a	598 a	11114 a
		profoxidim	200	10.7 a	26.8 a	28-ene. a	618 a	11820 a
2017	INIA Olimar	No herbicide	0	20.5 a	47.3 a	29-ene. a	701 a	10416 a
		metamifop	75	20.5 a	46.7 a	30-ene. a	651 a	10546 a
		metamifop	150	20.2 a	48.9 a	29-ene. a	616 a	10770 a
		profoxidim	100	17.1 b	48.4 a	31-ene. a	553 a	9528 a
		profoxidim	200	16.9 b	48.0 a	2-feb. b	525 b	10415 a
	INIA Merín	No herbicide	0	15.9 a	45.2 a	9-feb. a	688 a	12508 a
		metamifop	75	16.1 a	42.8 a	8-feb. a	647 a	11167 a
		metamifop	150	16.4 a	44.5 a	8-feb. a	623 a	10768 a
		profoxidim	100	15.3 a	42.2 a	9-feb. a	610 a	10846 a
		profoxidim	200	15.8 a	42.4 a	9-feb. a	603 a	11366 a
	Parao	No herbicide	0	15.8 a	35.4 a	29-ene. a	492 a	9691 a
		metamifop	75	16.7 a	35.6 a	29-ene. a	538 a	10983 a
		metamifop	150	16.7 a	36.0 a	29-ene. a	521 a	11437 a
		profoxidim	100	15.7 a	36.0 a	29-ene. a	551 a	10678 a
		profoxidim	200	15.5 a	35.4 a	29-ene. a	529 a	10672 a
Dunnett$_{0,05}$				2.4	3.4	2 days	156	2363

Conclusions

Field study of herbicide selectivity needs to be repeated many years and locations to identify appropriately weather conditions promoting herbicide injury and its association with rice variety on productivity.

References

Saldain, N.E., Sosa, B. ¿Cómo reducir los escapes de capín en sistemas intensivos en el uso de arroces Clearfield®? In: Zorrilla, G; Martínez, S.; Terra, J.A. ; Saravia, H. (eds.) Arroz 2018. Montevideo (UY):INIA, 2018 p.58-60 (INIA Serie Técnica; 246)

Rice Yield and N Use Efficiency in a Long-Term Rice-Pastures-Crops Rotations Experiment in Uruguay

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ABSTRACT

In Uruguay, rice frequently rotate with perennial pastures (mix of grasses and legumes) for livestock production. This allows sustain high yields, preserve natural resources, diversify incomes and minimize the use of agrochemicals. We evaluated the productivity and the partial factor productivity of N (PFPN: kg grain/kg N applied) in six no-tillage rice-pasture-other crops rotations (seasons 2016-2019) in a long-term experiment initiated in 2012 in Uruguay. Design was a randomized complete block with three replications and all rotation phases simultaneous. Treatments were established in a Natraquoll in a 30 years rice-pasture rotation field: 1) Rice-Rice-Long Pasture of *Festuca arundinacea*, *Trifolium repens* and *Lotus corniculatus* (RLP, 5yr); 2) Rice-Short Pasture of *Lolium multiflorum* and *Trifolium pratense* (RSP, 2yr); 3) Rice-Soybean-Soybean-Rice-Pasture of *Festulolium spp*. and *Lotus corniculatus* (RSyP, 6yr); 4) Rice-Soybean-Rice-Sorghum (RSyRSg, 4yr); 5) Rice-Soybean (RSy, 2yr); and, 6) Continuous Rice (CR, 1yr). Cover crops of *Lolium multiflorum* and *Trifolium alexandrinum L. grown* between cash crops in all rotations. Nitrogen fertilizer was splitted at V4 and R0 rice stages based in soil nitrogen mineralization potential of each rotation. The highest rice yield were observed in RSP, RSyP, RSyRSg and RSy (10.14 $Mg.ha^{-1}$) and the lowest in CR (9.50 $Mg.ha^{-1}$). Rice productivity after soybeans and pastures was 11.5% and 6.6% greater respectively than after rice or sorghum (9.38 $Mg.ha^{-1}$). Second rice of RLP had the poorest productivity (9.15 $Mg.ha^{-1}$), while rice after soybeans of RSyRSg had the greatest (10.80 $Mg.ha^{-1}$). The highest PFPN was observed in RSy and RSyP (121 $kg.kg^{-1}$) and the lowest in CR (60 $kg.kg^{-1}$). On average, rice seeded after pastures reached a higher PFPN (117 $kg.kg^{-1}$) compared with rice after rice (76 $kg.kg^{-1}$). For Mollisols under rice-pasture rotations in temperate-subtropical climates, there are rotation intensification alternatives (excluding CR) that allows sustain productivity maintaining high PFPN during their stabilization.

Key words: no-tillage, sustainable intensification, crop diversification

Critical nitrogen-dilution curves for rice in Uruguay

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Abstract

Uruguayan rice yield is on the top-five of the world. This productivity is achieved with relatively low inorganic N inputs. Research has developed a fertilization model for the early tillering moment (ETI) while from panicle initiation (PI) onwards, there is not practical available methods to assess the N status of the crop. The critical dilution N curves (CNDC) has proposed as a technology to check the N concentration against a critical N concentration during the length of the dry matter (DM) accumulation period. Two experiments with high yielding rice varieties (INIA Merin=indica and Parao=japonica) were conducted. Fertilization were made at ETI and PI with four N dose each one (0, 25, 50 and 100 kg ha^{-1}) generating 16 N treatments. Content of DM and N concentration were determined every 15 days from 15 days before PI until 50 days after this. Results showed that INIA Merin had a linear response in DM accumulation and yield (kg ha^{-1}) to N fertilization during the crop life, while Parao reach a maximum with 50 kg N ha^{-1}. High yield treatments of INIA Merin showed a CNDC lower than published indica CNDC, while Parao was closely related to published data. This suggest that more research must be continued to generate a CNDC for Uruguayan varieties and to test higher N doses to assess INIA Merin behavior in comparison to international published CNDC.

Keywords: Nitrogen Nutrition Index, Nitrogen Concentration, *Oryza sativa*, N use efficiency.

Introduction

In Uruguay rice rotates with pastures and country productivity (8 Mg ha^{-1}) is among the highest worldwide (Palmer, 2012). This yield is achieved with a high nitrogen use efficiency (> 100 kg kg^{-1}) compared with other rice systems (Pittelkow et al. 2016). The most frequent stages for N fertilization are at early tillering (ETI) and panicle initiation (PI). While farmers adopt the fertilization at ETI widely, in the last years the percentage of rice surface fertilized in both stages at national scale has been declining (GTA 2019). This was associated basically with a reduction in the labor costs when avoiding the plane used for this activity. Nevertheless, when N fertilization at ETI is the only input of inorganic N, it is not clear if this fertilizer topdressing could supply the total demand of N along the crop. Currently a N model to assess the N fertilization requirement from ETI to PI has been developed (Castillo et al. 2015), based on the potentially N mineralized (NPM), an anaerobic incubation of the soil (Waring and Bremner, 1964), measured around de seeding date. The same work has identified other N parameters (total N absorption) to assess the N status and requirements to be used at PI but this method has showed to be less accurate and impractical by farmers. The critical dilution N curves (CDNC) is a technology which relates the dry matter (DM) and the N concentration (%), which can be used as an assessment of the N status during the crop when the DM is higher than 1.5 Mg ha^{-1} (Justes et al. 1994). In the rice crop, this DM production is reached between ETI and PI stages so this technology can be useful to be used from PI onwards after the first N fertilization based on PMN. Some CNDC have been developed for indica and japonica rice and various climatic conditions (Sheehy et al., 1998; Huang et al., 2018; Ata-Ul-Karim et al., 2013). The aim of this work was to generate the first data set from a population with different N status and compare the best productive treatments with published CNDC.

Material and methods

Two experiments were installed at Paso de la Laguna INIA experimental station (33° 16' 23'' S; 54° 10' 24'' W; 22 MASL), during 2016/2017 growing season. Indica and japonica ideotypes were represented by the local varieties INIA Merín and Parao respectively. A split plot design with three replications were used being the big plot the N fertilization at ETI while the small one corresponded with the panicle initiation stage (PI). Four N dozes (0, 25, 50 and 100 kg ha^{-1}) were evaluated at TI and PI respectively, resulting in 16 N treatments, ranging from 0 to 200 kg ha^{-1}. From 15 days before PI (15 DBPI) to 50 days after PI (50 DAPI), aboveground biomass was collected every 15 days, removing 2 samples of 0.5 m per plot each time. Samples were dried for 48h (60 ºC) and milled (<0.5mm), previous to the N analysis. NIRS technique were used to assess the N determination with a previous calibration with the Kjeldahl method (R^2=0.99). Grain yield (kg ha^{-1}) were determined at the end of the crop, harvesting 16 m^2 at the center of the plot, adjusting to 13% of grain humidity.

Agronomic responses for each variety were evaluated using mixed models from the Infostat statistical package (Di Rienzo et al., 2008). In the model, N fertilization treatments at TI, PI and the interaction of both N fertilization stages were defined as fixed effect while the replications were defined as a random effect. Statistical differences were determined using the Fisher test (P≤ 0.05).

Results

Dry matter accumulation showed statistical differences only to N fertilization at ETI. Plant N concentration and grain yield responded to both N fertilization moments, ETI and PI while no interaction were detected.

Dose 100 N at ETI showed in all the measurement dates higher DM than 0 N, meanwhile 25 N and 50 N treatments were intermediate, except for 15DBP which 50 N not showed differences with 100 N (Table 1). At 50 DAPI, 100 N accumulated 38% and 19% more DM than 0 N and the intermediate doses, respectively (Table 1). Parao had a similar DM accumulation pattern where 100 N and 0 N were different through the crop cycle. Nevertheless, 25 N dose was close related with 0 N, and 50 N was intermediately between both groups. At 50 DAPI, 100 N dose generated an accumulation of DM of 47% and 21% higher than 0 N and 50 N treatments respectively.

Table 1: Dry matter accumulation and grain yield by N dose and fertilization moment.

	N Dose (ETI)	Dry matter accumulation					Yield	
		15DBP	PI	15DAPI	30 DAPI	50 DAPI	N Fertiliz-ETI	N Fertiliz-PI
		kg ha^{-1}						
INIA Merin	0	931 D	1950 D	4301 C	9797 C	13022 C	10630 C	11377 B
	25	1516 C	2827 C	5158 B	11363 B	14827 B	11840 BC	11545 B
	50	1943 B	4193 B	5662 B	12245 B	15581 B	12541 AB	12363 A
	100	2068 A	5486 A	7127 A	14120 A	18028 A	12909 A	12642 A
Parao	0	971 C	2273 D	6196 C	8791 C	_____	10685 C	10522 B
	25	1396 B	3196 C	6915 BC	10668 B	_____	11155 BC	11458 A
	50	1617 A	3859 B	7286 AB	11772 AB	_____	11681 AB	11599 A
	100	2058 A	4222 A	8033 A	12943 A	_____	11957 A	11898 A

Grain yield was had a strong correlation with N fertilization at ETI than PI (Table 1). No significant differences were found in the harvest index among N treatments reaching values between 0.55 y 0.65.

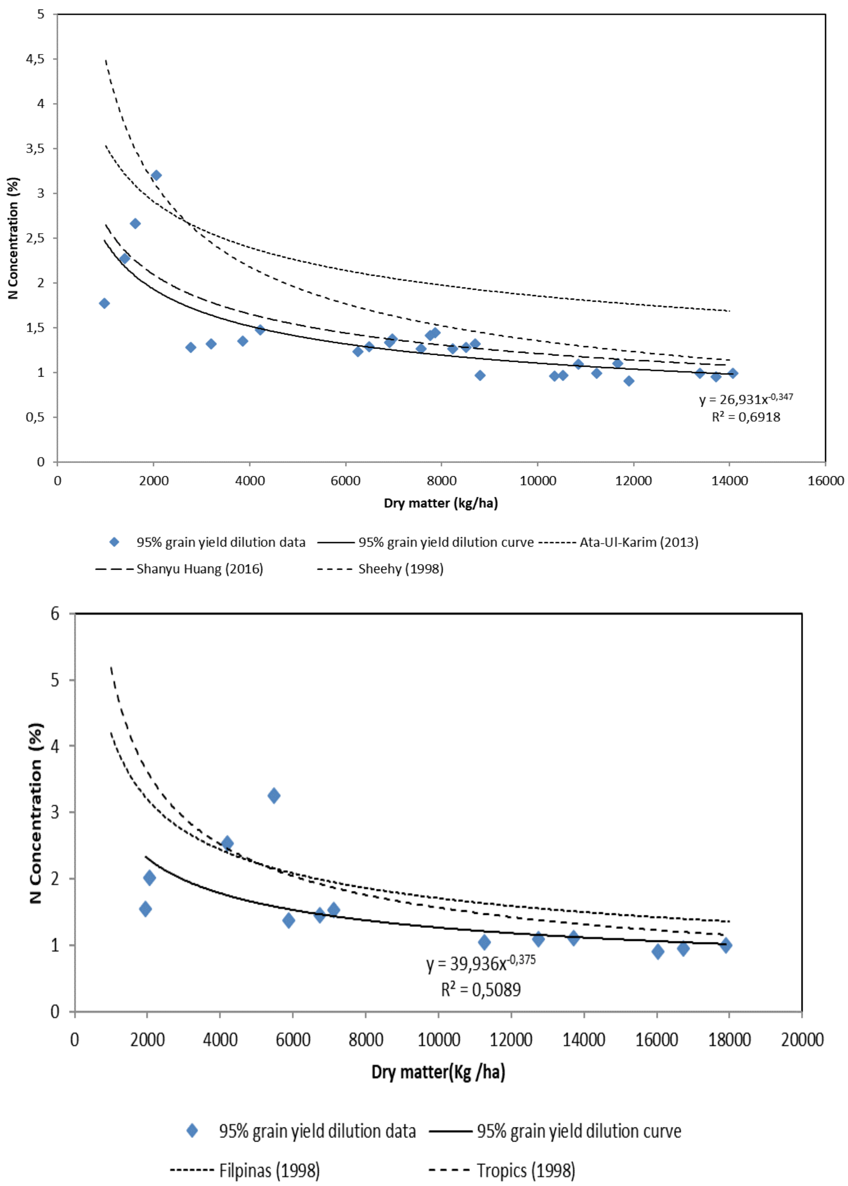

Figure 1: Dilution curve based on N treatments that achieved 95% of the relative yield plotted against international CNDC for: a) indica rice (below) and b) japonica rice (above).

For this first data-sets it was impossible to generate de CNDC because no critic point was possible to adjust for each measurement dates. This meant that an increase in DM an N concentration was observed with the increase in N doses, so the assumptions of the technique were not fulfilled. However, a dilution equation with treatments which reach more than 95% of the maximum yield was generated for each variety. For INIA Merín, the model was adjusted with treatments 50 N +50 N and 100 N+100 N (fertilization at ETI and PI respectively). When this dilution equation was plotted against the international CNDC it was observed a lower concentration in N in all the crop cycle for INIA Merin (figure 1 a). Results suggest that it would be possible achieve higher N concentration with higher N fertilization doses. This would also imply higher DM accumulation.

For Parao a dilution equation was constructed with treatments 50 N+25 N; 100 N+100 N; 50 N+50 N; 100 N+50 N and 100 N+25 N. In this case, the dilution observed was close to data published by Huang et al. (2018), for japonica rice in temperate climate (figure 1 b).

For Parao the only suitable CNDC is the one generated by Huang et.al, (2018) for japonica rice in temperate climate. This one is very similar to the curve obtained by modeling those treatments which reached 95% of the best grain yield. Given this results we can see how it would be useful to have the critical concentrations needed for each crop moment to manage fertilization more efficiently to fulfill its needs in case a deficit is detected.

Conclusions

Different results were observed when dilution curves of INIA Merin and Parao were compared with international CNDC. While for INIA Merin the dilution curve was lower (DM and N concentration) than international data Parao showed a close relation. Maybe the similarity of among climate conditions of both locations explain this behavior. In contrast for INIA Merin, CNDC data were generated in a different climate compared with Uruguay.

Results from this first dataset suggest that more research must to be conducted in order to generate CNDC for Uruguayan conditions, basically for INIA Merin. The exploration of higher N doses than used in this experiment will help to adjust a model were a critical N concentration for each DN content could be adjusted and a CNDC could be calculated.

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Critical nitrogen-dilution curves for rice in Uruguay

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Introduction

Uruguayan rice yield is on the top-five of the world. This productivity is achieved with a high nitrogen use efficiency (> 100 kg kg^{-1}) compared with other rice systems. The most frequent stages for N fertilization are at early tillering (ETI) and panicle initiation (PI). The critical dilution N curves (CDNC) is a technology which relates the dry matter (DM) and the N concentration (%), which can be used as an assessment of the N status during the crop when the DM is higher than 1.5 Mg ha^{-1} (Justes et al. 1994).

Objective

Generate the first data set from a population with different N status and compare the best productive treatments with published CNDC.

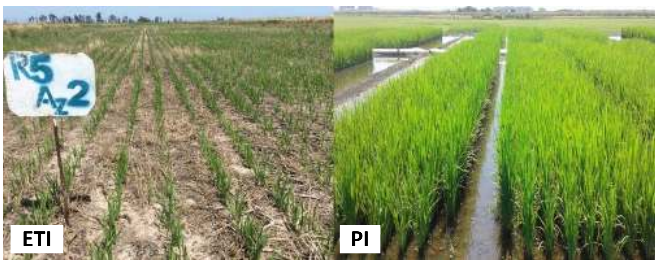
Material and Methods

Ideotypes: Indica (INIA Merin) and Japonica (Parao).

Experimental design: split plot design with 3 replications; big plot - the N fertilization at ETI; small plot – N at PI.

N doses: 4 evaluated at TI and PI respectively, resulting in 16 N treatments, ranging from 0 to 200 kg ha^{-1}.

Biomass was collected every 15 days. From that samples we calculated dry matter (DM) and sent a sample to the lab for nitrogen concentration analysis. Statistical differences were determined using the Fisher test (P≤ 0.05).

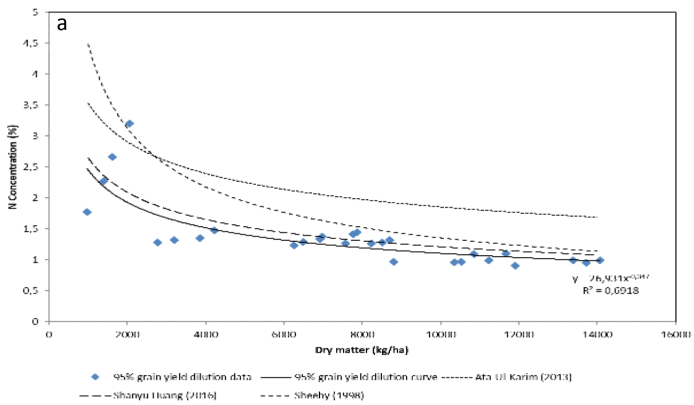


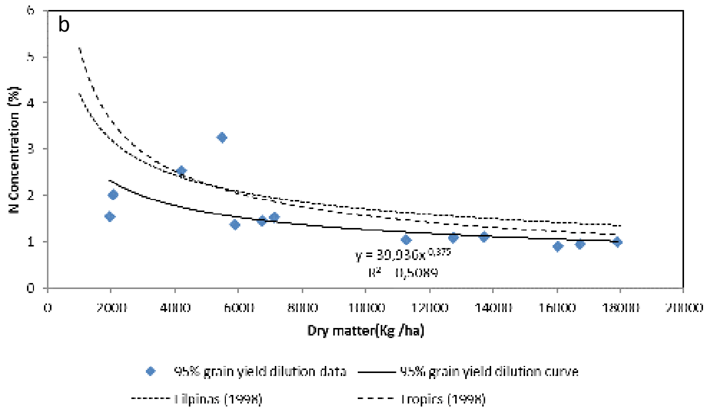
Results

Dry matter accumulation showed statistical differences only to N fertilization at ETI. Plant N concentration and grain yield responded to both N fertilization moments, ETI and PI, while no interaction were detected.

	N Dose (ETI)	Dry matter accumulation					Yield	
		15DBP	PI	15DAPI	30 DAPI	50 DAPI	N Fertliz -ETI	N Fertliz -PI
		kg ha^{-1}						
INIA Merin	0	931 D	1950 D	4301 C	9797 C	13022 C	10630 C	11377 B
	25	1516 C	2827 C	5158 B	11363 B	14827 B	11840 BC	11545 B
	50	1943 B	4193 B	5662 B	12245 B	15581 B	12541 AB	12363 A
	100	2068 A	5486 A	7127 A	14120 A	18028 A	12909 A	12642 A
Parao	0	971 C	2273 D	6196 C	8791 C	_____	10685 C	10522 B
	25	1396 B	3196 C	6915 BC	10668 B	_____	11155 BC	11458 A
	50	1617 A	3859 B	7286 AB	11772 AB	_____	11681 AB	11599 A
	100	2058 A	4222 A	8033 A	12943 A	_____	11957 A	11898 A

A dilution equation with treatments that reached more than 95% of the maximum yield was generated for each variety (a: Parao; b: INIA Merin), and plotted against international published CNDC.





Conclusions

While for INIA Merin the dilution curve was lower (DM and N concentration) than international data, for Parao were close related. Maybe the similarity among climatic conditions of both locations explain the behavior in Parao. In contrast for INIA Merin, CNDC data were generated in a different climate than Uruguay.

Results from this first dataset suggest that more research must be conducted in order to generate CNDC for Uruguayan conditions, basically for INIA Merin. The exploration of higher N doses than used in this experiment will help to adjust a model were a critical N concentration for each DM content could be adjusted and a CNDC could be calculated.

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Equivalence of Rice Hybrids with FullPage® technology

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ABSTRACT

In the crop season 2018/2019 several experiments were conducted in RS to validate the performance of FP technology. The objective of this work was to evaluate the tolerance and yield equivalence of Inov FP and XP113 FP hybrids compared to INOV CL, Titan CL and other commercial inbred rice varieties. FullPage hybrids showed improved tolerance to IMI herbicides than the commercial hybrids as well as similar yield potential. FullPage technology is a better alternative for managing weeds with optimized tolerance and flexibility for hybrid genotypes.

Key words: Fullpage; Imidazolinones; Hybrid Rice

1. Introduction

Hybrid rice is the ideal vehicle for bringing new herbicide resistance technologies in this crop. The use of F1 seeds, resulting from the cross two pure lines, allows the exploitation of heterosis or hybrid vigor that brings improved yield performance. Heterosis happens not only for yield but also for other characteristics including stresses tolerance. The hybrid platform contributes on the viability of the technology across time because of excellent seed purity, low risk of contamination with red rice and zero utilization of saved seeds by the farmers.

FullPage® (FP) technology refers to the utilization of herbicide tolerant rice hybrids and herbicides from the Imidazolinones (IMI) group. It was developed by a partnership between Adama and RiceTec. The main advantage is higher tolerance levels that reduces the risk of phytotoxicity in crop stress situations bringing more flexibility on the use of the technology to the farmers.

The objective of this work was to evaluate the equivalence in terms of tolerance and yield of Inov FP and XP113 FP hybrids compared to INOV CL, Titan CL and other commercial cultivars.

2. Material and Methods

Experiment 1. FullPage® Tolerance Test

In the 2018/2019 season were carried out experiments at Capão do Leão, RS (RiceTec Technological Center) and Santa Maria, RS (RiceTec Research Station). The objective of the trial was to evaluate the tolerance to IMI herbicides of FullPage hybrids and CL hybrids The experiment in Capão do Leão was sown on 11/11/2018 while in Santa Maria was sowed on 07/11/2018 The hybrids were INOV FP and XP113 FP, INOV CL and Titan CL. Herbicides were applied in the pre and post emergent (vegetative stage of application V4) format. The description of the treatments is listed in Table 1.

Treat	Preview emerging	Postemerging
T1	Imazapir + Imazapique (140g/ ha^{-1}	Imazapir + Imazapique (140g/ ha^{-1})
T2	imazapique + Imazapir (0.3L/ ha^{-1})	Imazetapir + (1.5L/ ha^{-1})
T3	imazapique + Imazapir (0.3L/ ha^{-1}	imazapique + Imazapir (0.3L/ ha^{-1})
T4	imazapique + Imazapir(0.3L/ ha^{-1}) + Trifluralin (4.0L/ ha^{-1})	Imazetapir + (1.5L/ ha^{-1})
T5	Imazetapir (1.2L/ ha^{-1})	Imazapir(1.2L/ ha^{-1}+ Trifluralin (4.0L/ ha^{1})
T6	Imazetapir(1.2L/ ha^{-1}) + Premerlin (4.0l/ ha^{-1})	Imazetapir + (1.2L/ ha^{-1})
T7	imazapique + Imazapir (0.2L/ ha^{-1})+clomazone (0.6L/ ha^{-1})	Imazetapir + (1.2L/há)
T8	Imazapir + Imazapique (140g/ ha^{-1})+clomazone 0.6L/ ha^{-1})	Imazapir + Imazapique (140g ha^{-1})

Table 1. Herbicide treatments used in experiment 1.

1

The treatments corresponding to combinations of four genotypes and eight herbicides were evaluated in a factorial design allocated in RCB design with three replications. The experimental unit consisted of plots with 1.22 meters wide and 6.0 meters long. The management of fertilization and irrigation was carried out following the technical recommendations for rice cultivation (SOSBAI, 2016).

Herbicide application was carried out with a CO_2 pressurized sprayer operating at a pressure of 20 bar, fitted with a 6-point teejet 110.02 bar. The tolerance of the genotypes to the herbicides was measured by evaluating phytotoxicity at 7, 14 and 21 days after application (DAA) through a visual scale where zero score equals to no herbicide injury and 100 means plants completely dead. For the evaluation of the productivity it was considered 12.2 m² in the central area of each plot. Harvest was done with a Plot Combine (Wintersteiger Model Classic) and the yield was expressed as kg of clean and dry rice (13% moisture) per hectare. The data was analyzed trough ANOVA and the means were compared by the Scott-Knott test, with a 5% probability level of error.

Experiment 2. Large-scale trial (larges)

The second experiment was carried out in 4 locations in the state of Rio Grande do Sul: Santa Maria, Pelotas, Bagé and Capão do Leão also in the 2018/2019 crop. Side-by-side strip trials were designed to evaluate yield between FullPage® and CL versions in semi-commercial scale areas.

The genotypes used in the experiment were INOV CL, INOV FP, Titan CL, XP113FP, Irga 424 RI, Lexus CL and Guri INTA CL. The seed treatment was the standard recommend by RiceTec, the seed rate was 40 kgha-1 in hybrids and 80 kg ha-1 for inbred varieties and agronomic management was done following technical recommendations for rice cultivation (SOSBAI, 2016).

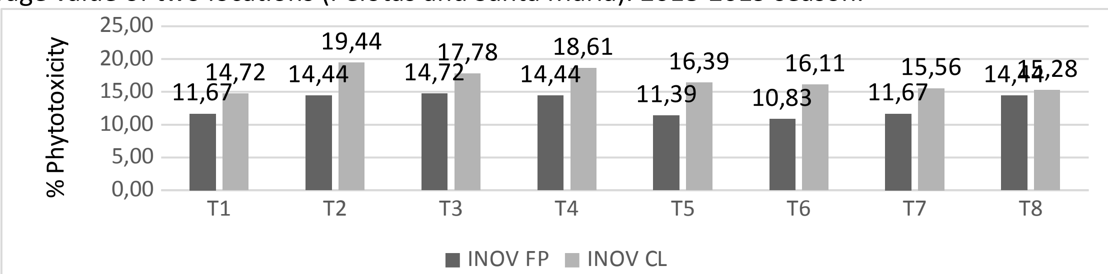
The herbicide treatment was a combination of pre and post emergent (the vegetative stage of application was when the crop was in V4 stage) herbicides. In pre emergence the treatment was Imazapir + Imazapique (140g.ha^{-1}) + Clomazone 0.6 g.ha^{-1}. In post emergence the treatment was Imazapyr + Imazapic (140 g.ha^{-1}). For sowing and harvesting, commercial equipment available on the producer's farm was used.

The experimental design was a strip test plot where the experimental unit consisted of plots 6 meters wide and 42.0 meters long. For evaluation purposes, it was considered 54.2 m² central area in each plot as the experimental unit. The treatments were applied with a mechanical ground sprayer. The evaluated parameter was yield expressed by kg of clean and dry rice (13% moisture) per hectare.

3. Results and Discussion

The results of experiment 1 indicated a significant gain in tolerance of hybrids with FullPage technology. The Inov FP genotype had a lower phytotoxicity than Inov CL in all herbicide treatments evaluated. For example, in treatment T1, the average phytotoxicity of Inov FP was 11.6 while Inov CL had 14.7. In T2, the treatment that caused the highest phytotoxicity, the average was 14.4 for Inov FP and 19.44 for Inov CL, indicating a reduction of 5 points (Figure 1). A similar pattern was observed in the other treatments except for T8 where the numerical value for Inov FP was lower but the difference non-significant.

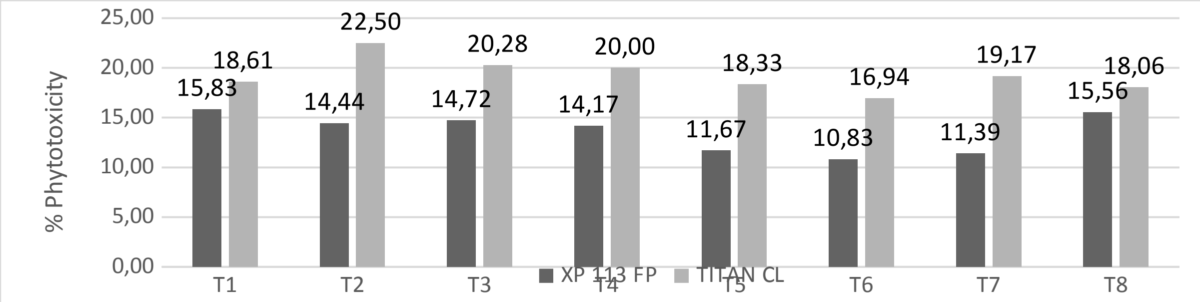
Figure 1: Comparison of Inov FP vs Inov CL hybrids for phytotoxicity in 8 IMI herbicide treatments. Average value of two locations (Pelotas and Santa Maria). 2018-2019 season.



** Refers to statistical analysis of Scott-Knott test mean comparison, with 5% probability of error.

The XP113 FP performance in terms of tolerance was also superior to Titan CL in all treatments evaluated. In the commercial treatment T1, the average phytotoxicity for XP113FP was 15.83 while Titan CL had 18.61. Similarly, at T2 there was a significant reduction, XP113FP had a phytotoxicity of 14.44 and Titan CL had an average of 22.5 (Figure 2). A similar trend can be observed for the rest of the treatments, XP113 FP always had a significant lower phytotoxicity than Titan CL.

Figure 2. Comparison of XP113 FP vs Titan CL hybrids for phytotoxicity in 8 IMI herbicide treatments. Average value of two locations (Pelotas and Santa Maria), 2018-2019.



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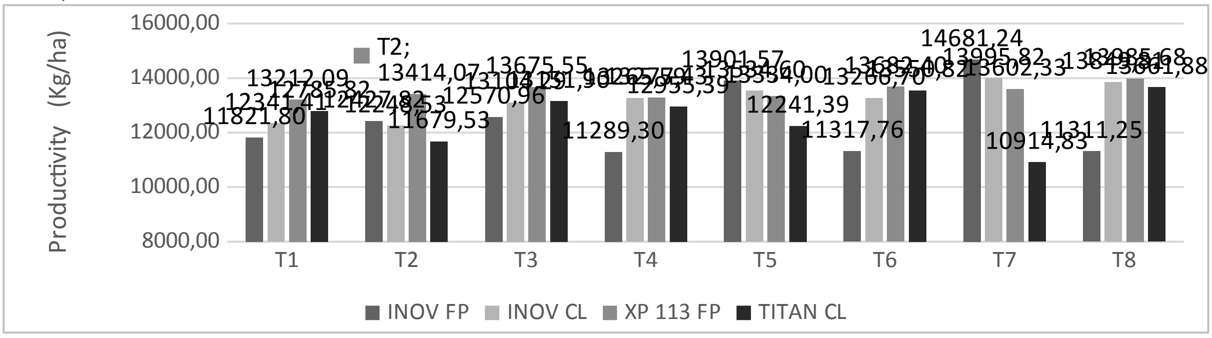
There was a differential response of genotype yield to herbicide treatments. Inov FP had a higher productivity than Inov CL in treatments T2, T5 and T7; however, Inov CL was superior in T1, T3, T4, T6 and T8 treatments. Analyzing XP113 FP was superior to Titan CL in treatments T2, T5 and T7 and similar to Titan CL in the other treatments (Figure 3). These results can be attributed to the tolerance genes used that have a different response depending on the herbicide composition and the productive capacity of each hybrid.

Figure 3. Results regarding the average yield of the genotypes evaluated in the two sites trials, 2019

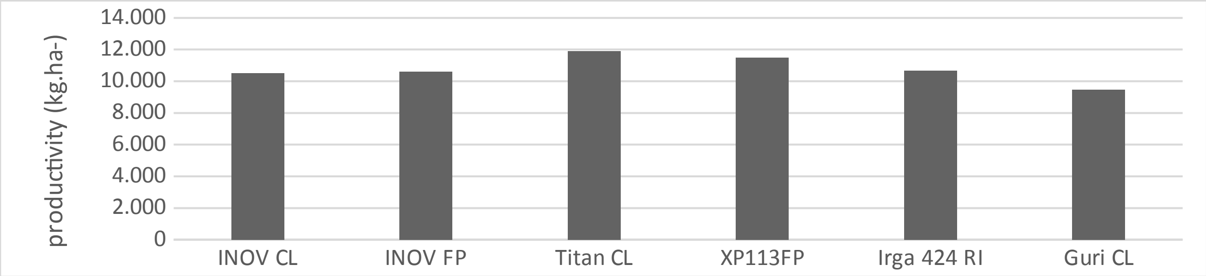


** Referring to statistical analysis of Scott-Knott test mean comparison with 5% probability of error.

Productivity comparisons in side-by-side strip trials (experiment 2) indicated that hybrids with FullPage technology are equivalent to commercial hybrids and have an important productive advantage over the commercial control of the same cycle as we can see in Figure 4. The most productive hybrid was the Titan CL with an average of 11.900 kg. ha^{-1} followed by the XP113FP with 11.484 kg. ha^{-1}. These two materials had a productive advantage of 2.434 kg.ha^{-1} and 2.018 kg. ha^{-1} when compared to cultivar Guri INTA CL. In the case of Inov FP, the average was 10.604 kg.ha^{-1} with productive advantage of 1.138 kg ha^{-1} when compared to Guri INTA CL. The average of Inov CL was 10514 kg ha^{-1} with a productive advantage of 1048 kg. ha^{-1}.

This response shows that the performance of the materials remained unchanged when the genes responsible for herbicide tolerance were changed. The change on the genes did not affected yield potential. There is a higher yield potential among the Titan CL and XP 113 FP hybrids with cycle of 125 and 120 days respectively. By analyzing the productive potential of Inov FP and Inov CL we can conclude that both has similar yield potential to the variety IRGA 424 RI but the hybrids have a reduced cycle in average of 15 days in relation to the variety.

Figure 4: Average productivity in kg / ha in side-by-side strip trials. 2018/19 harvest.



** Referring to statistical analysis of Scott-Knott test mean comparison with 5% probability of error.

Conclusions

FullPage hybrids® have adequate tolerance to IMI herbicides and are equivalent to commercial hybrids in terms of productivity and yield advantage.

FullPage technology® is a new alternative for the management of red rice and other weeds with greater tolerance and flexibility as well as high yield potential.

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Alternatives for handling rice straw to favor its decomposition in direct sowing systems

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ABSTRACT

Rice irrigation by flooding provides this crop with particular characteristics, including at harvest, when it causes difficulties for machinery traffic due to the high soil water content. In addition to this, a large amount of green material is left on the soil, impedes later work to the point where the straw can be affect rice establishment in the following season. The above is complicated by the use of direct sowing, which achieves positive results, both in lowering costs and recovering soil, although there is few knowledge of how the decomposition at planosol soils in South Brazil. The main objective of this study were to find out how tools can be best used for improving decomposition of residue from harvesting rice grown under direct sowing and their impact on soil compactation. A experiment was arranged in a randomized complete block design, with four replicates, was performed. Three decomposition methods of rice straw were studied: passing a roller crimper over rice straw; passing a roller compactation over rice straw; and the maintenance of the straw on the surface with desiccation (no-tillage). The fallow was the maintenance of the straw on the surface without desiccation and tested a method most commum at South Brazil : the incorporation of the straw in dry soil with a disc (conventional). The main results were the use of a roller compactation or roller crimper on the rice straw reduced until 70 % rice straw and viabilized the next rice direct sowing.
Key words: roller crimber, no-tillage, *Oryza sativa L.*

1. Introduction

Sowing date is the main factor for the rice grain yield. One determining factor of delay in sowing time has its origin, fundamentally, in the absence of adequate management in rice post-harvest areas and preparation of the areas during the off-season period. In this scenario, the traditional form of soil preparation is the incorporation of the soil with dry soil or water depth, followed by planning. When this system occurs during fall it is called minimum system and represents 70 % of the southern Brazil rice areas and, when it occurs in spring, it is called conventional system.

However, the difficulty of soil preper management and high production costs, especially in relation to fuel, have demanded search for cheaper post-harvest soil management that does not interfere with the sowing season. Within this scenario, there is the possibility of direct sowing on the rice field if harvesting with dry soil is possible. The problem is that rice has a harvest index of 0.50 (Bird et al., 2001). This means that the production of 10 t ha^{-1} of grain results in the production of 10 t ha^{-1} of low-quality straw, with a high lignin content and high C/N ratio (Massoni, 2011). Besides, harvest occurs when the temperatures begin to fall, and the photoperiod is lower, causing a reduction in the decomposition rate by microorganisms (Lobo Júnior et al., 2004).

To study the effect of different post-harvest management of rice straw, Massoni (2011) concluded that during the rice off-season, regardless the type of management, there is a reduction in only half of the dry matter of the remaining stubble, regardless whether the straw is left on the soil surface or incorporated to it with a disc. That way, to keep rice stubble on the soil surface could be an alternative to management that involves tillage, reducing costs and avoiding delays in sowing the new crop.

Although there is already information about the benefits of direct sowing in flooded rice areas, it has a low adoption along to the rice farms, due to the difficulty in reducing during the off-season rice the large amount of straw produced by this area. In this sense, the objective of the present work was to identify strategies to maximize the decomposition of rice straw, allowing the sowing of the new season without harming the establishment and consequent rice grain yield.

2. Material and Methods

The experiment was conducted under natural conditions, in experimental-teaching lowland areas of the Instituto Rio Grandense do Arroz (IRGA), at Cachoeira do Sul, state of Rio Grande do Sul, Brazil. It began in the 2017 off-season and was finalized in the season crop of 2018/19. The soil of the experimental area is classified as Ultisol soil (Soil US Soil Taxonomy Entisol), with the following physicochemical characteristics in the 0-20 cm depth: water pH (1:1) = 4.6; phosphorus (P) = 3.7 mg dm^{-3}; potassium (K) = 0.14 cmolc dm^{-3} and organic matter (OM) = 10.0 g kg^{-1}. The local climate is humid subtropical, classified as Cfa by the Köppen classification system. The average annual temperature and rainfall are 19.2 °C and 1,708 mm, respectively (Maluf, 2000).

The area was sourced from flooded rice stubble, sown with IRGA 424 RI rice cultivar in two growing seasons (2016/17 and 2017/18), with 9,500 kg ha^{-1} of the remaining dry matter from the straw at harvest.

Treatments were composed by the following post-harvest rice straw management: maintenance of the straw on the surface without desiccation (**fallow**); maintenance of the straw on the surface with desiccation (**no-tillage**); incorporation of the straw in dry soil with a disc (**conventional**); maintenance of the straw on the surface (no-tillage) with subsequent upturning with a **roller compaction** to crush the straw into the soil surface; and maintenance of the straw on the surface (no-tillage) with subsequent upturning with a **roller crimber** to crush the straw into the soil surface. The experimental design was in randomized blocks, with four replicates, and each plot measured 5 m wide by 3,05 in length.

Rice straw was desiccated in no-tillage, roller compactation and roller crimber treatments using the herbicide glyphosate, 15 days after the harvest, at a dose of 1,800 g i.a ha^{-1}. In the management that did not incorporate the straw on the ground, the rice straw was upturned with a roller compaction and roller compactation passing two times in opposite directions, three weeks after the straw desiccation, to keep it in contact with the soil. This operation was performed in dry soil. The conventional system was implanted with a disc in dry soil near to rice sowing.

Prior to the treatment application, a characterization of the amount of rice dry mass present in the area was performed and after treatment application the amount of dry mass present in each treatment was quantified in the treatments that kept the straw on the surface. This evaluation was performed until the sowing date of flooded rice, on 10/25/2018 and 11/03/2018. For this, in two areas of 0.25 m^2 of each plot, all the plant material present in the soil was removed (except material from spontaneous plants) and it was submitted to drying in oven with 60 ° C until constant weight. It was later converted to kg ha^{-1}.

In the 2018/19 harvest, at rice sowing date, the mechanical resistance to penetration was evaluated by using the Falker penetrometer, at a depth of 0 to 40 cm. Concomitantly, soil density and soil macro and soil microporosity were determined by a methodology developed by EMBRAPA (2013) in the treatment using the roller crimber and in the conventional system.

Data were subjected to analysis of variance using the F test at 5 % probability of error. When significant, the means were compared by the Scott-Knot test.

3. Results and Discussion

Figure 1 shows the Remaining Dry Mass (RDM) of rice straw as a function of the adopted management. The result of desiccate or not desiccate the straw depended on the evaluated growing season. In the 2017/18, desiccation increased by 4 % the decomposition of rice straw in relation to not desiccate, while in 2018/19, this difference was 7 %. Even though there were no major differences between desiccation or not of rice straw, this management is a fundamental condition to avoid regrowth that can influence the weed seed bank. Moreover, desiccation management alone does not guarantee significant decomposition rates, remaining more than 50 % of RDM on the soil until sowing date.

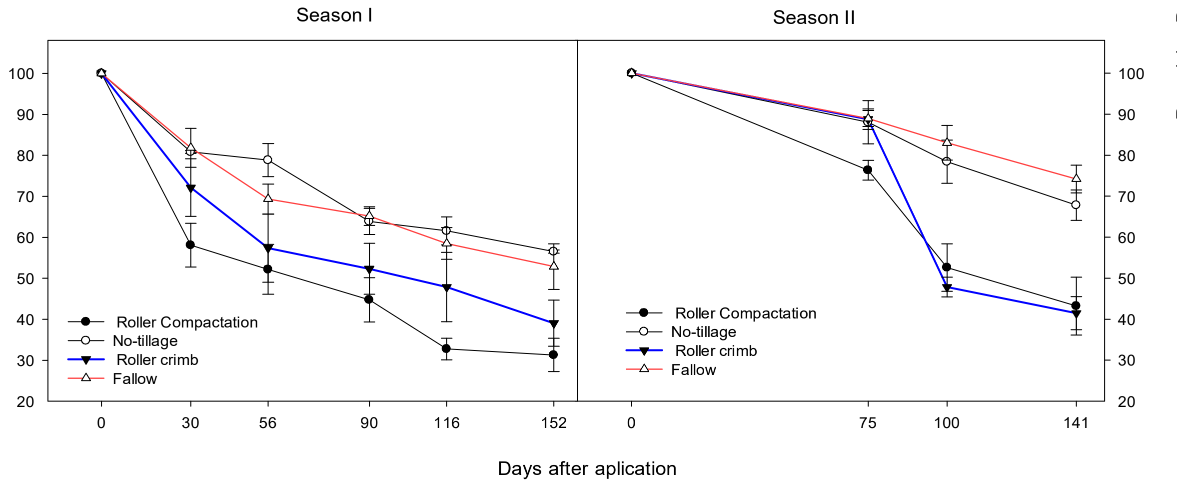

Figure 1. Remaining dry mass as a function of postharvest management, in days after treatment application, in the 2017/18 (Season I) and 2018/19 growing seasons (Season II). Cachoeira do Sul, Brazil, 2019.

On the other hand, when desiccation was associated with equipment that favored straw contact with the soil, the RDM was reduced to approximately 30 %, depending on the season, regardless of whether roller crimber or roller compactation was used, demonstrating that there is a need for adopt strategies to increase the decomposition of rice straw.

The performance between the roller crimber and the roller compactation was similar, although the roller crimber showed a reduction of 8 % more in the first growing season and 3 % in the 2018/19 season. The roller crimber seems to be more efficient because it makes a small incorporation of the straw in the soil, besides breaking it, increasing the contact surface for microbial decomposition. Even so, it took a period of more than 100 days after management to achieve more than 50 % of the RDM, demonstrating that there should be planning in the actions to stimulate the decomposition of this high C/N ratio material. It is also important to emphasize that the area remained throughout the off season, in excellent drainage, a fundamental condition for obtaining these results.

The use of implements, in addition to favoring the decomposition of straw, decreased the mechanical resistance to penetration, as shown in figure 2. The treatments with the highest amount of straw fallow and with dissecation were the managements that presented the highest mechanical resistance to penetration, together with conventional system, mainly in the 10-20 cm layer.

However, it was in the treatments with the straw maintenance on the surface that the soil density was higher in the 0-5 cm layer (Table 1), a fact linked to the accumulation of pressures exerted on machine traffic and the non-mobilization of the soil with disc. The effect of conventional system was also reflected in soil macroporosity, which was higher in the superficial layer (0-5 cm). There was no influence of preparation systems on either microporosity or total porosity, agreeing with other authors who have reported similar results, requiring several years of direct sowing to record physical differences (BOTTAS et al., 2015).

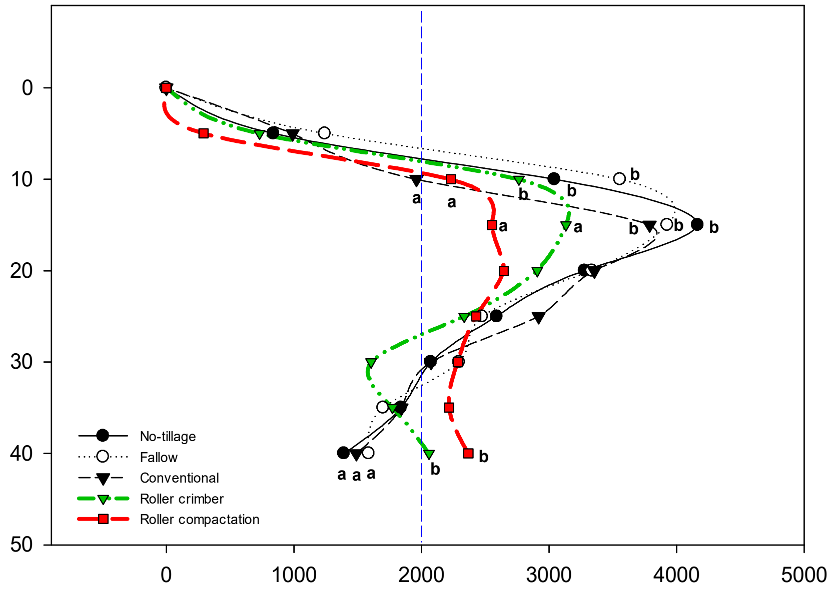

Figure 2. Mechanical resistance to penetration on flooded rice at sowing date as a function of postharvest management of rice straw in the 2018/19 growing season. Cachoeira do Sul, Brazil, 2019.

Table 1. Bulk density and soil microporosity, total porosity and macroporosity as a function of soil tillage systems conventional and no-tillage at different depths. Cachoeira do Sul, Brazil, 2019.

Depth	Density (g cm^3)	Microporosity (g cm^3)	Total Porosity (g cm^3)	Macroporosity (g cm^3)
		Conventional system		
0-5	1.69 Bb[1]	0.33^{ns}	0.54^{ns}	0.20Aa
5-10	2.19a	0.33	0.42	0.08 b
10-15	2.11a	0.42	0.50	0.08 b
		Roller crimber		
0-5	2.02 A	0.36^{ns}	0.44^{ns}	0.08B
5-10	2.22^{ns}	0.33	0.42	0.08^{ns}
10-15	2.13^{ns}	0.34	0.41	0.07 ^{ns}
Mean	2.06	0.35	0.45	0.10
Cv (%)	4.52	23.61	18.20	33.34

X

[1]Lowercase letters compare management within each column (depth); Upperletters compares the post-harvest management average each layer. ns= no significant at 5 % level

Conclusions

Postharvest management that approximates rice straw of soil favors its decomposition and decreases the mechanical resistance to penetration at rice sowing date.

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Increasing rice productivity by improving population and nitrogen management

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ABSTRACT

One of the main goals in agriculture nowadays is to maximize production efficiency, through resources optimization by improving processes. New cultivars with a different growing strategy, including length of cycle, canopy structure, “stay-green” capability, and disease-tolerance, push us to review the known recommendations in basic management factors, as plant density and nitrogen (N) fertilization. INIA Merín, an *indica*-type cultivar recently released in Uruguay was tested under various plant densities and N fertilization topdressing doses, in three contrasting sites and for two years. Growing parameters, including yield and yield components, were analyzed using mixed models. Seed density directly influenced plant population, reaching the optimum plant number with 110 to 150 kg ha^{-1} seed. No interaction between plant density and nitrogen fertilization was recorded for any variable. Biomass and grain yield were affected by both analyzed parameters, being N more relevant in magnitude. A denser plant population and a higher N amounts increased grain yield by 9 % and 24%, respectively. A linear regression between yield and nitrogen amount was set, inducing the hypothesis that there is still yield to explore through an augment in nitrogen topdressing.

Key words: plant density, fertilization, INIA Merín, *indica* type.

1. Introduction

Reaching high efficiency in productivity is one of the main goals in nowadays production systems, and the release of new modern cultivars needs to be complemented with management information. The cultivar INIA Merín (Perez de Vida et al, 2016) has an erect plant structure, long cycle, very high yield potential, an important response to nitrogen and is blast-resistant, having low risk of lodging and is also more tolerant to shoot diseases. Although a local objective recommendation system about N fertilization exist (Fertiliz-Arr), it was created with other cultivar types. Management of some basic production factors as plant population and nitrogen response have to be assessed in various environments (soil types, temperatures), in order to check those recommendations under different conditions in the different rice production areas.

2. Material and Methods

Six experiments distributed in three sites: Paso de la Laguna (PL), Pueblo del Barro (PB) and Paso Farías (PF), from East to North, and during two years (2016-2017 and 2017-2018 for PL and PF, or 2017-2018 and 2018-2019 for PB). The cultivar used was INIA Merín, *indica* type, a long grain and long cycle, high productive and blast resistant. Four plant densities and four N treatments were combined (Table 1), and installed over fields where rice rotated with pastures (grasses and legumes), using direct seeding or minimum tillage over a previous summer land preparation.

Table 1. Seed density (viable seeds m^{-2}), seed rate (kg ha^{-1}) and nitrogen fertilization (kg N ha^{-1}) treatments.

Seed density (SD) Viable seeds m^{-2}	**Seed rate (SR)** Kg seeds ha^{-1}	**Nitrogen treatments** Kg N ha^{-1}
1: 195	60-70	1: control; 0 (ETI) + 0 (PI)
2: 325	100-110	2: medium; 45 (ETI) + 30 (PI)
3: 488	150-160	3: Fertiliz-Arr[1]; X (ETI) + Y (PI)
4:650	190-210	4: high; 68 (ETI) + 45 (PI)

ETI: at early tillering; PI: at panicle initiation; [1] local rice fertilization recommendation system created by INIA Uruguay (http://www.inia.uy/investigaci%C3%B3n-e-innovaci%C3%B3n/programas-nacionales-de-investigaci%C3%B3n/Programa-Nacional-de-Investigacion-en-Produccion-de-Arroz/fertiliz-arr-una-herramienta-inia-para-la-fertilizaci%C3%B3n-en-arroz).

The experimental design was a factorial in randomized blocks with three replicates, with all the combinations between plant densities and N treatments, in 16 m^2 plots each. Measurements included plant recovery (PR, in number and percent), aboveground biomass in panicle initiation - R3 (BiR3) and previous harvest (BiHa), NDVI at R3 (NDVIR3), grain yield (Yi), yield components (panicles per area –Pa-, filled-grains per panicle –Fgp-, 1000 grains weight –W1000-, floret sterility -%St-) and harvest index (HI). The statistical analyses were carried out with Infostat (www.infostat.com.ar), using mixed models where plant density, N fertilization and their interaction were considered fixed factors, and year, site and block as random factors. Regression analysis was also explored for grain yield and N.

3. Results and Discussion

Plant density directly influence PR; though more viable seeds m^{-2} resulted in more plants m^{-2} (Figure 1), the percentage of PR diminished from 195, 325, 488 and 650 viable seeds m^{-2} (64%, 64%, 52% and 46%, respectively). A minimum plant stand recommendation for rice field conditions in Uruguay is usually between 200 and 250 plants per m^2.

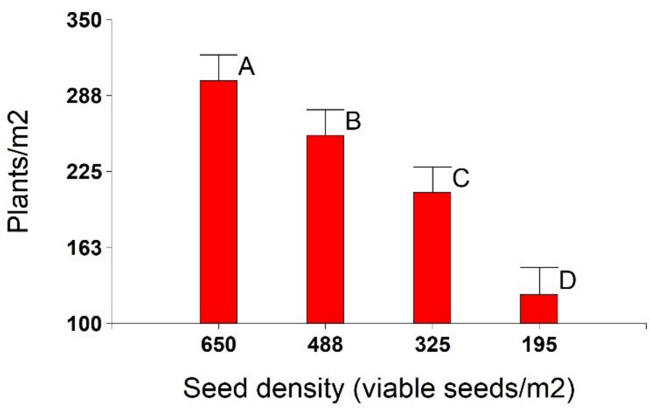

Figure 1. Average plants recoveries for different viable seed densities, in the six experiments (three sites, two years) evaluated.

All the other variables were analyzed by both factors, plant density and N, and in the majority of them, both had significant individual effects (Table 2). No interactions were detected for any variable analyzed.

Biomass changes at R3 were mainly driven by N, with a significant gap of 700-800 kg ha^{-1} within the control and the other N treatments. As seen in previous studies (Marchesi and Castillo, 2016), NDVIR3 was directly associated by N, with a positive response from 0.53 to 0.70 between extreme treatments. At harvest, both N and density had effects, with greater differences determined by N, of 3000 to 4000 kg ha^{-1}. The HI was quite stable with values of 0.51-0.52, with no changes between treatments, denoting the relevance in trying to obtain an abundant biomass crop.

Table 2. Significance of the plant density and nitrogen treatments over the variables analyzed for INIA Merín in six experiments (three sites and two years)

Variables	**Factors**			R^2
	Plant density	Nitrogen	Pl Den*Nitro	
BiR3	0.0153	<0.0001	ns	0.73
NDVIR3	ns	<0.0001	ns	0.69
BIHa	0.0019	0.0002	ns	0.70
HI	ns	ns	ns	--
Yi	0.0061	<0.0001	ns	0.72
Pa	0.0032	0.0116	ns	0.59
Fgp	<0.0001	ns	ns	0.75
W1000	ns	<0.0001	ns	0.56
%St	ns	ns	ns	--

BiR3= aboveground biomass in panicle initiation (R3); NDVIR3= NDVI at R3; BiHa= biomass previous harvest; HI= harvest index; Yi= grain yield; Pa= panicles per area; Fgp= filled-grains per panicle; W1000= 1000 grains weight; % St= floret sterility; ns = no significant.

Relative to yield components, Pa was dependent on both density and N, with a positive response: higher density implied higher Pa, and the equivalent with N, with a maximum increase of 10% in both cases. However, Fgp was only affected by seed density and in an inverse relationship, associated to the number of Pa. On the other hand, W1000 was influenced just by N. Yet, floret sterility did not changed in a clear pattern with the analyzed variables.

Respect to Yi, both variables density and N were relevant. Higher plant density and higher N amounts increased Yi 9 % and 24%, respectively. In a more detailed analysis of the association between Yi and N, within each plant density level or in average, a linear regression was adjusted (Figure 2).

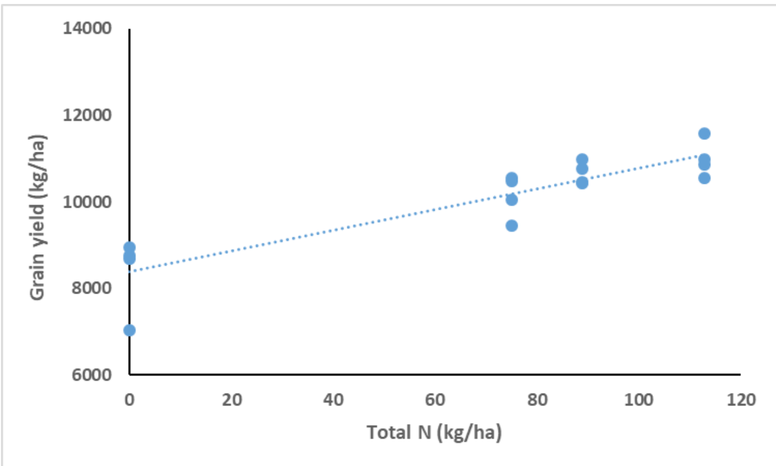

Figure 2. Linear regression between total N applied and grain yield for all plant densities, INIA Merín.

From an agronomic approach, it is known an excess of N could induce a decline in grain yield, due to different reasons (Dobermann and Fairhust, 2000). Therefore, a polynomial model would be more suitable, but higher N rates must be explored in order to know the point or region on the equation where the amount of N would be detrimental for Yi in INIA Merín. This concept is in accordance with Fabini et al (2020), where they could not find a detrimental N amount for this cultivar, also with 200 kg ha^{-1}, as it was reported for older ones, as INIA Olimar (Deambrosi and Mendez, 2007).

Conclusions

For most of the analyzed variables, this cultivar responded to nitrogen and seed density, but with different magnitudes. Plants per unit area and percent recovery were positive and inversely influenced by plant density, respectively. The plant density to achieve the optimal population of 200 to 250 plants m^{-2} for INIA Merín was among 105 and 155 kg ha^{-1} seeds, depending on the year.

Plant density affected biomass, grain yield and some yield components, as panicles per area and filled grains per panicle. On the other hand, N also affected biomass, NDVI, grain yield, panicle per area and 1000 grains weight. The magnitude of the N effect was higher than plant density, for most of the variables.

Grain yield was positively affected by both plant density and N, but yield increases were 9 % and 24% for both factors, respectively. Therefore, the relevance of N is undoubted. Moreover, the adjusted linear regression would imply INIA Merín could be able to explore higher yields if more N is applied. An even harvest index between 0.51 and 0.52 would assure that the additional biomass produced by an extra N availability for the crop, finally end in grain yield.

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Increasing rice productivity by improving population and nitrogen management

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Introduction

- Main goal: reaching high efficiency on rice productivity
- New cultivar: INIA Merín.
- A local objective recommendation system about N fertilization exist (**Fertiliz-Arr**), created with previous cultivar types.
- Management of some basic production factors as plant population and N response have to be assessed in various environments.

Objective

To obtain the best combination of plant population and N fertilization for the novel cultivar INIA Merín in Uruguayan rice production conditions.

Material and Methods

- 6 experiments, 3 sites (PL, PB and PF, from East to North), 2 years.
- Cultivar: INIA Merín, *indica*, long grain and long cycle, high productive and blast resistant, low risk of lodging and tolerant to shoot diseases.
- Plant densities (4) and N treatments (4) (Table 1), installed over fields where rice rotated with pastures, using direct seeding/minimum tillage over a previous summer preparation.

Table 1. Seed density (viable seeds m^{-2}), seed rate (kg ha^{-1}) and nitrogen fertilization (kg N ha^{-1}) treatments.

Seed density (SD) Viable seeds m^{-2}	**Seed rate (SR)** Kg seeds ha^{-1}	**Nitrogen treatments** Kg N ha^{-1}
1: 195	60-70	1: control; 0 (ETI) + 0 (PI)
2: 325	100-110	2: medium; 45 (ETI) + 30 (PI)
3: 488	150-160	3: Fertliz -Arr[1]; X (ETI) + Y (PI)
4:650	190-210	4: high; 68 (ETI) + 45 (PI)

ETI: at early tillering; PI: at panicle initiation; [1] local rice fertilization recommendation system created by INIA Uruguay.

INIA Merín, March 2019, PB

A: Density 4 – N 4

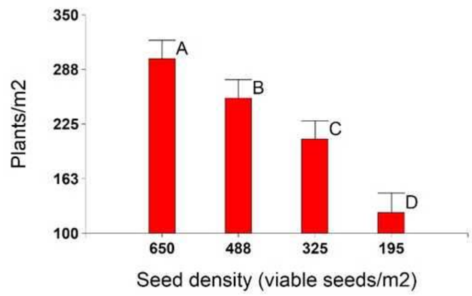
B: Density 2 – N 4

- Experimental design: factorial in randomized blocks, 3 replicates, with all the combinations between plant densities and N treatments;
- 16 m^2 plots.
- Measurements: plant recovery (PR, in number and %), aboveground biomass in PI- R3 (BiR3) and previous harvest (BiHa); NDVI at R3 (NDVIR3), grain yield (Yi), yield components (panicles per area, filled-grains per panicle, 1000 grains weight, floret sterility); harvest index (HI).
- Statistical analyses: mixed models (plant density, N fertilization and interaction as fixed factors; year, site and block as random factors). Regression analysis for grain yield and N.
- Statistical package: Infostat (www.infostat.com.ar).

Results and Discussion

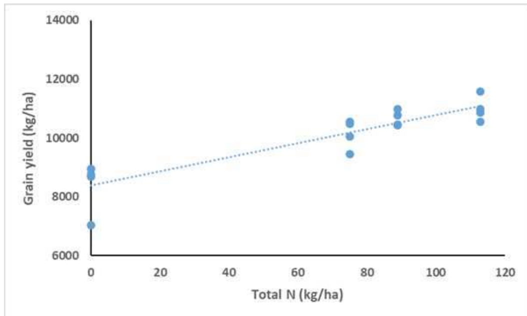
- SD directly influence PR (Figure 1), while the % PR decreased from 195, 325, 488 and 650 vs m^{-2} (64%, 64%, 52% and 46%, respectively).

Figure 1. Average plants recoveries for different viable seed densities.



- For all the other variables, both, plant density and N had significant individual effects. No interactions were detected for any variable analyzed.
- BiR3 was dependent on N, with a significant gap of 700-800 kg ha^{-1} (control vs N). NDVIR3 was also associated by N, with a positive response from 0.53 to 0.70. At harvest, both N and density had effects, with greater differences by N, of 3000 to 4000 kg ha^{-1}. The HI was quite stable (0.51-0.52) among the N treatments.
- For Yi, both density and N were relevant: ↑plant density and ↑N, increased Yi 9 % and 24%, respectively.
- The association between Yi and N, within each plant density level or in average, adjusted a linear regression (Figure 2).

Figure 2. Linear regression between total N applied and grain yield for all plant densities, INIA Merín.



- From an agronomic approach, an excess of N could induce a decline in grain yields. Therefore, a polynomial model would be more suitable, but higher N rates must be explored to know the region on the equation where the amount of N would be detrimental for Yi in INIA Merín.

Conclusions

- INIA Merín responded to N and seed density for most of the analyzed variables, being the magnitude of the N effect higher, in general.
- Grain yield was affected by both plant density and N, but yield increases were 9 % and 24%, respectively, denoting the relevance of N. Moreover, the adjusted linear regression would imply INIA Merín could be able to explore higher yields if more N is applied, based on the observed data of stable harvest index.

Influence of Application Timing on Urea-Nitrogen-15 Recovery in Irrigated Rice

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ABSTRACT

Under a context of natural resources exhaustion, nitrogen (N) fertilization practices that reduce waste while maintaining crop productivity are required. Nitrogen is the nutrient required in large quantities by rice and the optimum application timing management may assure profitability and sustainability to the production system. This study aimed to evaluate the influence of nitrogen application timing on rice grain yield, total nitrogen uptake and urea-nitrogen-15 recovery. A greenhouse experiment was conducted at research station of Embrapa Temperate Agriculture in Pelotas-RS, Brazil, during the 2018/2019 growing season. Five nitrogen management treatments: control (0 kg N ha^{-1}) and the recommended nitrogen rate for rice (120 kg N ha^{-1}) associated to four fertilizer nitrogen application timings (one split: 100% at the three-leaf stage of development (V3); two split: 50% at V3 stage + 50% at the panicle initiation stage (R0) or 67% at V3 stage + 33% at R0 stage; and three split 33,3% at V3 stage + 33% at the seven-leaf stage (V7) + 33% at R0 stage. A completely randomized experimental design with five treatments and three replications was used. The nitrogen source was ^{15}N-labelled urea. The results showed significant effect of nitrogen rate and application timing on rice grain yield and total nitrogen uptake. The effect of the nitrogen rate was greater than the application timing, although there was a positive trend toward higher yield and nitrogen uptake with multiple N split. Nitrogen in rice derived from urea was also benefited by the multiple splitting of nitrogen fertilization, highlighting the effect of the triple splitting that provided higher recovery of urea-N-15 comparing to single and double split. This behavior was also verified for urea-nitrogen-15 recovery. These findings indicate the benefit of nitrogen fertilization fractionation for rice, enhancing yield performance, total N uptake and N use efficiency of urea.

Key words: *Oryza sativa*, nitrogen fertilizer, grain yield, nitrogen use efficiency.

Influence of Application Timing on Urea-Nitrogen-15 Recovery in Irrigated Rice

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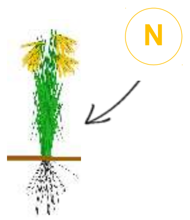
Introduction

Nitrogen: high demand by rice

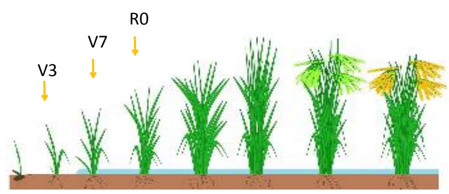


↑High productivity

↓ Low waste

N fertilization management practices that reduce waste while maintaining crop yield are required

N fertilization timing



Optimum application timing management may assure profitability and sustainability to the production system

Objective

To evaluate the influence of nitrogen application timing on rice grain yield, total nitrogen uptake and urea-nitrogen-15 recovery.

Material and Methods

- Greenhouse experiment
- Local: Embrapa Temperate Agriculture , Pelotas-RS, Brazil
- Soil: Planossolo Háplico (Typic Albaqualf)
- Period: November 2018 to March 2019
- Nitrogen source and rate: ^{15}N-labelled urea, 120 kg ha^{-1} of N
- Treatments:

  T1: No nitrogen (control)

  T2: 100% N at the three-leaf stage (V3)

  T3: 50% N V3 + 50% at the panicle initiation stage (R0)

  T4: 67% N V3 + 33% R0

  T5: 33% N V3 + 33% at the seven-leaf stage (V7) + 33% R0
- Completely randomized experimental design with three replications
- Measured variables:: rice grain yield, total nitrogen uptake and urea-nitrogen-15 recovery
- Statistical analysis: ANOVA; Tukey test ($p < 0.05$)

Figure 1. Greenhouse trial views at the vegetative (a) and (b) and reproductive phase (c). Pelotas-RS, Brazil. Growing season 2018/2019.

Results

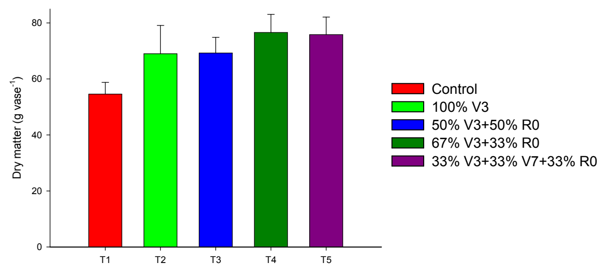


Figure 2. Influence of nitrogen application time on total dry matter production of the rice plants. Pelotas-RS, Brazil. Means not sharing a letter are significantly different according to Tukey test ($p<0.05$).

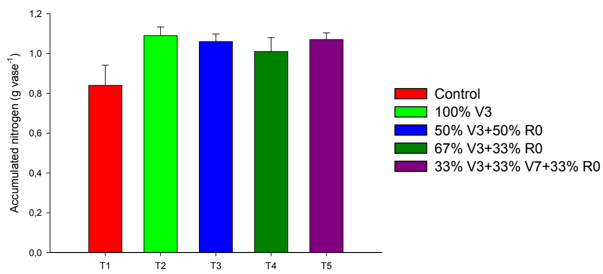


Figure 3. Influence of nitrogen application time on total nitrogen accumulation of the rice plants. Pelotas-RS, Brazil. Means not sharing a letter are significantly different according to Tukey test ($p<0.05$).

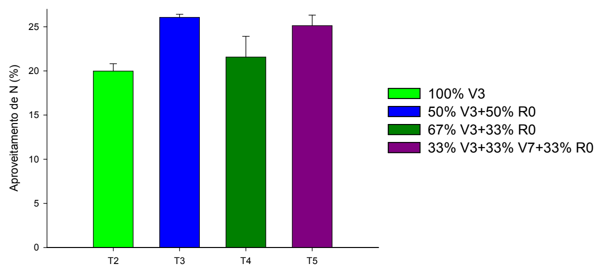


Figure 4. Influence of nitrogen application time N-urea utilization by the rice plants. Pelotas-RS, Brazil. Means not sharing a letter are significantly different according to Tukey test ($p<0.05$).

Conclusions

- Nitrogen fertilization increases yield and nitrogen accumulation of the rice plants.
- Split application of nitrogen improves the nitrogen use efficiency of urea by rice.

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Soil Carbon Stocks in Lowlands of Southern Brazil: Effect of Soil Tillage System and Crop Rotation System

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ABSTRACT

Studies suggest that changes from conventional tillage system (CT) to no tillage system (NT) increase Soil Carbon Stock (SCS). Likewise crop rotation systems can also influence SCS. This study aimed to evaluate the effect of soil tillage system and crop rotation system on SCS and their particle size fractions in a Planossolo (Typic Albaqualf) cultivated with irrigated rice. The study was developed at the research station of Embrapa Temperate Agriculture in Capão do Leão-RS, Brazil. Undisturbed soil samples were collected after the harvest of rice growing season, in April 2019. Treatments combined two tillage systems (CT and NT) and two crop rotation systems (Maize-Rice: maize-maize-maize-irrigate rice and Rice: continuous irrigated rice system) arranged in a split plot design with three replications. Tukey test was used for mean comparisons ($p < 0.05$). SCS, particulate organic C stock (POC) and C associated with minerals stock (CAM) were evaluated in 0-0.025m and 0.025-0.05m depths. Considering 0-0.025m depth, SCS values varied from 4.39 Mg ha^{-1} for Maize-Rice/CT to 6.31 Mg ha^{-1} for Maize-Rice/NT. Areas previously cultivated with irrigated rice showed intermediate SCS values (5.05 Mg ha^{-1} for Rice/NT; and 5.15 Mg ha^{-1} for Rice/CT). POC stock showed statistical difference only for soil tillage system, where NT favored POC stock increase (1.37 Mg ha^{-1} for CT; and 2.25 Mg ha^{-1} for NT), regardless of crop rotation system. Rice/NT presented higher CAM stock (3.73 Mg ha^{-1}). In 0.025-0.05 m depth, Rice/CT showed higher SCS value (6.32 Mg ha^{-1}). It was verified statistical difference for SCS between Maize-Rice/CT (1.45 Mg ha^{-1}) and Maize-Rice/NT (1.89 Mg ha^{-1}). Rice/CT presented higher CAM stock values (4.45 Mg ha^{-1}). These were higher than Rice/NT (3.93 Mg ha^{-1}) and Maize-Rice/CT (3.87 Mg ha^{-1}). Overall, NT systems decreases SCS in the continuous irrigated rice system, whereas increases values in maize-rice system.

Key words: irrigated rice, maize, rotation system, conventional tillage, no-tillage.

Soil Carbon Stocks in Lowlands of Southern Brazil: Effect of Soil Tillage System and Crop Rotation System

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Introduction

- Studies suggest that canges from conventional tillage system (CT) to no tillage system (NT) increase Soil Carbon Stock (SCS).
- Likewise crop rotation system can also influence SCS.

Figure 1. Experimental site – Irrigated rice under CT and NT system.

Objective

To evaluate the effect of soil tillage system and crop rotation system on SCS and their particle size fractions in a Planossolo Háplico (Typic Albaqualf) cultivated with rrigated rice.

Material and Methods

- Research Station of Embrapa Temperate Agriculture.
  - Capão do Leão, RS, Brazil
- Soil samples were collected after the harvest of rice growing season.
  - April, 2019
- Planossolo Háplico (Typic Albaqualf).

Treatments
- 2 tillage systems → conventional tillage and no tillage
- 2 crop rotation systems → Maize-rice and Rice-rice

Depths (m)
- 0.00 – 0.025
- 0.025 – 0.05

- Soil samples were submitted to physical fractionation. (Cambardella and Elliot, 1992)
  - Soil Carbon Stock (SCS);
  - Particulate Organic Carbon Stock (POC);
  - Carbon Associated with Minerals Stock (CAM).
- Carbon content in fraction were determine by dry combustion analyzer.
  - Split plot desing;
  - Three replications;
- Tukey test was used for mean comparisons (p<0,05).

Figure 2. Disturbed and undisturbed soil samples.

Results

Table 1. Soil carbon stock (SCS), particulate organic carbon stock (POC) and carbon associated with mineral stock from a Typic Albaqualf under diferent tillage system and crop rotation system.

	SCS			Label C POC			Not labile C CAM		
				Mg ha^{-1}					
				0.00 – 0.025 m					
	CT	NT	Mean	CT	NT	Mean	CT	NT	Mean
Rice-Rice	5,15$^{ns\ NS}$	5,05^{ns} B	5,10	1,42	1,88	1,65^{ns}	3,73^{ns} A	3,17$^{ns\ NS}$	3,45
Maize-Rice	4,39 b ^{NS}	6,31a A	5,35	1,31	2,62	1,97^{ns}	3,07^{ns} B	3,57$^{ns\ NS}$	3,32
Mean	4,77	5,68		1,37 b	2,25 a		3,4	3,37	
				0.025 – 0.05 m					
	CT	NT	Mean	CT	NT	Mean	CT	NT	Mean
Rice-Rice	6,32 a A	5,49 b ^{NS}	5,91	1,87$^{ns\ NS}$	1,56$^{ns\ NS}$	1,72	4,45 a A	3,93 b ^{NS}	4,19
Maize-Rice	5,32^{ns} B	5,98$^{ns\ NS}$	5,65	1,45 b ^{NS}	1,89 a ^{NS}	1,67	3,87^{ns} B	4,09$^{ns\ NS}$	3,98
Mean	5,81	5,74		1,66	1,74		4,16	4,01	

Conclusions

Overall, no tillage system decrease soil carbono stock in continuous irrigated rice system, whereas increases values in maize-rice system.

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Temperate Climate Rice Microorganisms Collection

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ABSTRACT

In the Temperate Climate Multifunctional Microorganisms Collection, established more than 20 years ago, 218 strains of diazotrophic bacteria with potential for biological nitrogen fixation (FBN) and promotion of plant growth (PCP) of irrigated rice, cultivated in the lowlands are preserved from Rio Grande do Sul, Brazil. The enrichment of this collection results from obtaining isolates from irrigated rice cultivars [(BRS Atalanta (31); BRS Fronteira (24), BRS Querência (127); BRS Pelota (18) and BRS Taim (18)], developed by Embrapa and indicated for ecosystems in the extreme south of Brazil, in the Pampa Biome. In the prospection of BRS Taim and BRS Pelota, aerobic diazotrophic endophytic bacteria, isolated from leaves, stems and roots, characterized as endophytic diazotrophic microorganisms, obtained with capable of rice PCP. When analyzing the interaction of these strains with BRS Fronteira, BRS Querência and BRS Pampa, fifteen strains showed the ability to colonize these cultivars with positive interaction for PCP variables and Relative Index of Chlorophyll. In prospecting the cultivar BRS Querência, 115 endophytic diazotrophic bacteria (BED) and PCP associated with leaves + stems, roots and rhizosphere were obtained, with strains of *Pseudomonas fluorescens* (stems + leaves) and *Azospirillum amazonenses* present in all morphological structures of this cultivar. In the selection of BED with potential for FBN and PCP of BRS Pampa, strains of *Bacillus*, *Rhizobium* and *Pseudomonas*, coming from stalks and rice leaves of the BRS Pelota and BRS Taim, demonstrated an associative character with BRS Pampa. When evaluating the agronomic efficiency of these intercropped strains in combination with 90 kg N ha^{-1} of coverage, the productivity of BRS Pampa obtained above 10,000 kg ha^{-1}. The occurrence of these BEDs inside stalks and leaves of rice indicates the diversity of beneficial genera with different mechanisms of interaction with the plant, which can result in increased productivity of this cereal

Key words: bacteria, biological nitrogen fixation, *Oryza sativa L.*, promotion of plant growth.

Temperate Climate Rice Microorganisms Collection

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Introduction

In the Temperate Climate Multifunctional Microorganisms Collection, established more than 20 years ago, 218 strains of diazotrophic bacteria with potential for biological nitrogen fixation (FBN) and promotion of plant growth (PCP) of irrigated rice, cultivated in the lowlands are preserved from Rio Grande do Sul, Brazil.

Enrichment

Preservation

Objective

Report the functionality and application of isolated strains of irrigated temperate rice.

Material and Methods

- Isolates from irrigated rice cultivars:
- ❖ BRS Atalanta (31)
- ❖ BRS Fronteira (24)
- ❖ BRS Querência (127)
- ❖ BRS Pelota (18)
- ❖ BRS Taim (18)

Figure 1. Evaluation of strains in a greenhouse, under sterile substrate. BRS Pampa

- Prospection of BRS Taim and BRS Pelota:
- ❖ aerobic diazotrophic endophytic bacteria, isolated from leaves, stems and roots, characterized as endophytic diazotrophic microorganisms, obtained with abillity to promote the growth of rice plants (PGP).

Figure 2. Formation of characteristic veil of bacteria of the genus *Azospirillum*, in semi-solid NFb medium

Figure 3. Colonies of bacteria of the genus *Pseudomonas*, which promotes the growth of rice plants, in PCA medium

Results

❖ Cultivar BRS Querência: 115 endophytic diazotrophic bacteria (BED) and PGP associated with leaves + stems, roots and rhizosphere were obtained, with strains of *Pseudomonas fluorescens* (stems + leaves) and *Azospirillum amazonenses* present in all morphological structures of this cultivar.

Figure 4. BRS Querência.

Figure 5. Strains of *Pseudomonas fluorescens*

❖ Selection of BED with potential for FBN and PGP of BRS Pampa: strains of *Bacillus*, *Rhizobium* and *Pseudomonas*, coming from stalks and rice leaves of the BRS Pelota and BRS Taim, demonstrated an associative character with BRS Pampa.

Figure 6. Strain evaluation experiment with BRS Pampa

Figure 7. Consortia of strains isolated from stalks and leaves of BRS Pelota and BRS Taim

❖ The agronomic efficiency of these intercropped strains in combination with 90 kg N ha^{-1} of coverage, the productivity of BRS Pampa obtained above 10.000 kg ha^{-1}

Conclusions

The occurrence of these BEDs inside stalks and leaves of rice indicates the diversity of beneficial genera with different mechanisms of interaction with the plant, which can result in increased productivity of this cereal.

Crop Rotation as a Strategy to Mitigate Greenhouse Gas Emissions in Lowlands of Southern Brazil

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ABSTRACT

Crop diversification with rainfed species in rotation to irrigated rice constitutes an alternative to increase the sustainability of production systems in lowlands of Southern Brazil. The decrease in the period of anoxic environment influence crop yield and interfere in the dynamics of soil carbon and nitrogen and, consequently, in greenhouse gases emissions. Therefore, the aim of this study was to evaluate the potential of sorghum and soybean crops in mitigating methane (CH_4) and nitrous oxide (N_2O) emissions from lowlands of Southern Brazil, compared to irrigated rice. A field trial was conducted in a Typic Albaqualf at research station of Embrapa Temperate Agriculture in Rio Grande do Sul, Brazil. Measurements of CH_4 and N_2O fluxes were performed using static chambers with three replications. The air sampling for CH_4 and N_2O soil emissions analysis was conducted at least once a week throughout the growing season. Methane emissions were influenced by the cultivated species. Irrigated rice provided CH_4 emissions higher than sorghum and soybeans. This result is due to the anaerobic environment where rice is grown, favoring the activity of methanogenic bacteria. On the other hand, lower CH_4 emissions from sorghum and soybeans were related to the condition of oxidized soil, except after high rainfall events. Cumulative N_2O emissions from rice were lower than those from sorghum and soybean. The highest N_2O emissions in rainfed crops were associated with nitrogen supply, via fertilization, for sorghum, or the biological fixation of N from soybean. Rice rotation with rainfed crops reduced CH_4 emissions and increased N_2O emissions, compared to irrigated rice monoculture. The reduction in CH_4 emissions was more significant than the increase in N_2O emissions. Crop diversification, with the insertion of rainfed crops in rotation to irrigated rice, is a promising alternative to mitigate GHG emissions in the lowlands of Southern Brazil.

Keywords: paddy rice, soybean, sorghum, methane, nitrous oxide.

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Crop Rotation as a Strategy to Mitigate Greenhouse Gas Emissions in Lowlands of Southern Brazil

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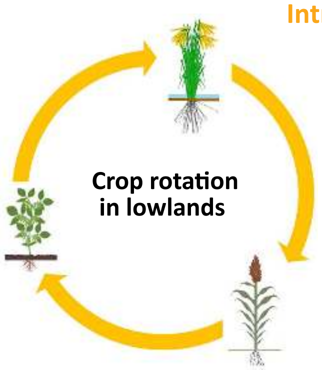
Introduction



- ✓ Increases sustainability
- ✓ Decreases anoxic period
- ✓ Interferes soil carbon dynamics
- ✓ Interferes nitrogen dynamics
- ✓ Affects greenhouse gas emissions:

↓ CH_4 emissions ↑ N_2O emissions

Crop diversification with rainfed species in rotation to irrigated rice constitutes an alternative to increase the sustainability of production systems in lowlands of Southern Brazil.

Objective

To evaluate CH_4 and N_2O emissions from sorghum and soybean grown in lowlands, comparing to irrigated rice emissions.

Material and Methods

- Local: Terras Baixas Experimental Station of Embrapa Temperate Agriculture, Capão do Leão, State of Rio Grande do Sul, Brazil
- Soil: Planossolo Háplico (Typic Albaqualf)
- Period: crop season 2015/2016
- Soil tillage system: conventional
- Off season crop: ryegrass
- Treatments (summer crop):
  - Irrigated rice
  - Soybean
  - Sorghum
- Completely randomized experimental design with three replications
- CH_4 and N_2O evaluations: static chamber method
- Sampling frequency: at least once a week (9:00 to 11:00h AM)
- Measured variables: CH_4 and N_2O fluxes, seasonal N_2O and CH_4 emissions
- Descriptive statistical analysis: mean and standard deviation

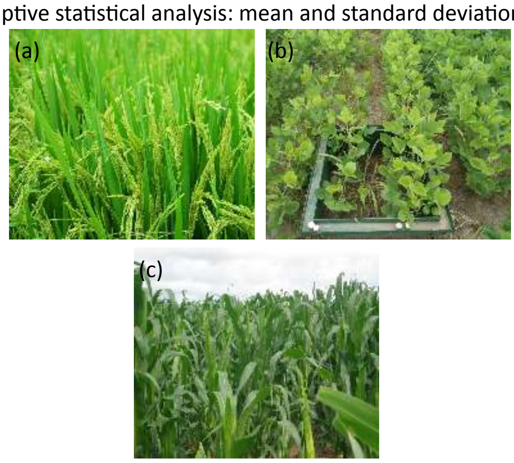


Figura 1. Experimental area grown with irrigated rice (a), soybean (b) and sorghum (c). Capão do Leão-RS, Brazil.

Results

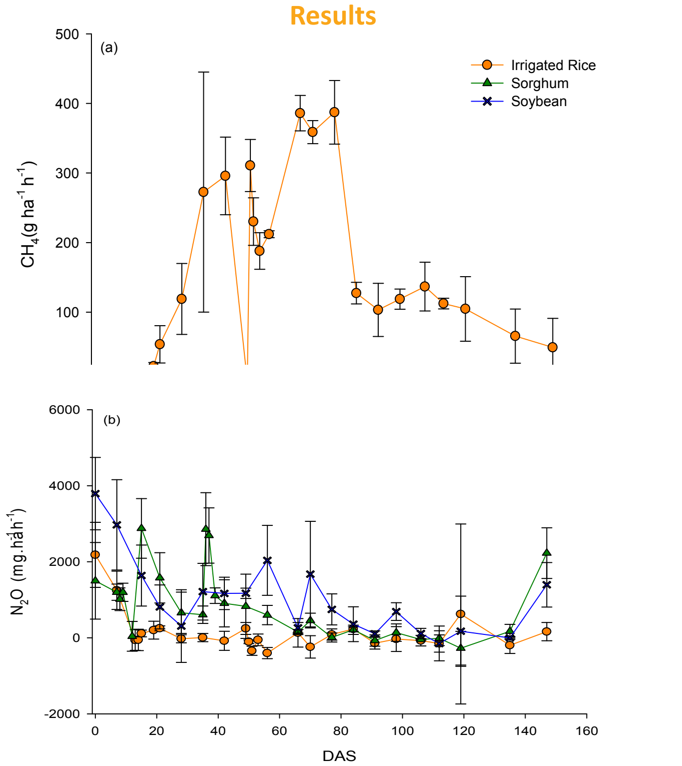


Figure 2. CH_4 (a) and N_2O (b) fluxes from a Typic Albaqualf grown with irrigated rice, soybean, and sorghum. Error bars represent the standard error of the means. Capão do Leão-RS, Brazil.

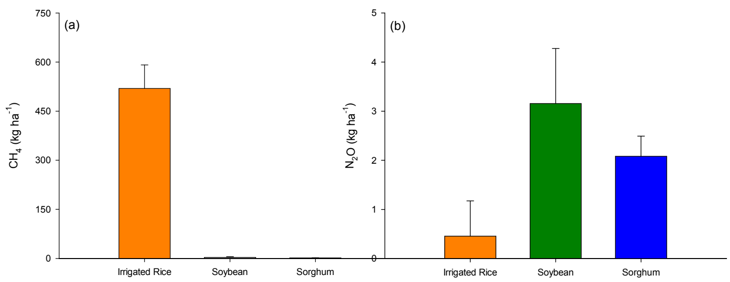


Figure 3. Seasonal CH_4 (a) and N_2O (b) emissions from a Typic Albaqualf grown with irrigated rice, soybean, and sorghum. Error bars represent the standard error of the means. Capão do Leão-RS, Brazil.

Conclusions

Soybean and sorghum grown in lowlands reduces CH_4 emissions and increases N_2O emissions, comparing to rice. The reduction of CH_4 emissions is more significant than the increase of N_2O emissions.

Crop diversification with rainfed crops grown in rotation to irrigated rice, is a suitable alternative to mitigate greenhouse gas emissions in lowlands of southern Brazil.

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Performance of Rice Crop as Function of Seed Treatment and Irrigation Method in Temperate Climate

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Abstract— we aimed with this study to evaluate the performance of irrigated rice plants, as a function of seed treatment composition and crop irrigation management. Two factors were studied in the experiment: (A) irrigation management (continuous or intermittent); and (B) seed treatment composition (complete, fungicide only, insecticide only, no treatment + clomazone, and no treatment without herbicide). Standak and Vitavax-Thiram were used as insecticide and fungicide standards, respectively. The Guri Inta CL rice variety, treated three days before planting, was adopted. Irrigation was established twenty days after emergence. In continuous irrigation, a 7 cm mean water layer was maintained during the experimental period; in intermittent irrigation, a 10 cm initial water layer was established and then water supply was interrupted until 10-15% of the plot was aerated, when the 10 cm layer was reestablished. Twelve days after sowing, rice emergence was evaluated. Twenty days after crop emergence, the rice plant height was evaluated. Thirty days after emergence, plant density was again measured. At the end of the crop cycle, grain yield was evaluated. Data were analyzed based on the 95% confidence intervals. There is neither evidence of interference from the differential seed treatment on the agronomic performance of rice, nor differences resulting from their interaction with the irrigation management.

Keywords— *Oryza sativa*, establishment, development, productivity.

Introduction

In Rio Grande do Sul, the recommended time for planting rice is between September and November, depending on the locality, cultivar cycle and cultivation system, among others (Recommendations..., 2016). In early season planting, the seeds can remain for many days in the soil seed bank until the temperature and humidity conditions that trigger germination are reached. Thus, most producers end up by treating seeds in order to avoid problems of establishment of rice seedlings due to unfavorable climatic conditions (Lobo, 2008), even with no recommendation of this procedure for the South Brazilian rice fields (Recommendations…, 2016). Early season planting promotes the matching of the reproductive period with the greatest solar radiation abundance (December / January), which may contribute to increase the rice grain yields (Mertz et al., 2009).

The action of pre-emergent herbicides, both those affecting the germination process and emergence, as well as those affecting rice seedlings, should also be considered in the initial crop establishment. Among these herbicides, one of the most used in rice cultivation is clomazone. Therefore, damage to the initial plant population, often attributed to pests and diseases, may result from herbicide phytotoxicity. Thus, there are some "protectors", also known as "safeners", which when used in conjunction with seed treatment confer to the plant greater herbicide tolerance (Oliveira Jr and Inoue, 2011).

The mixture of different products in seed treatment, however, has generated complaints by rice farmers, who claim to observe reduction in the stand of rice plants when seed treatment includes two or three chemicals with different purposes. These same farmers raised the hypothesis that this possible negative interaction between products used in seed treatment may be linked to water management in the rice field. The products used for seed treatment in some regions of Brazil include the insecticides thiamethoxam, imidacloprid and fipronil, and the fungicides carboxin and thiram, among others (Lobo, 2008).

Thus, the objective of this work was to evaluate the performance of irrigated rice plants, as a function of seed treatment composition and crop irrigation management, in Brazilian Temperate Environment.

Material and Methods

The experiment was installed in a systematized area of the Embrapa Temperate Climate, Terras Baixas Experimental Station, Capão do Leão-RS, geographic coordinates -31.8153, -52.4698, in strip-plot design (Tantiphanwadi and Ayudthya, 2017), with plots measuring 25 m^2. Two factors were studied: (A) irrigation management, being continuous irrigation (C_), and intermittent irrigation (I_); and (B) seed treatment composition, being complete treatment with fungicide and insecticide (FI); treatment with fungicide only (Fung); treatment with insecticide only (Inset); without seed treatment, with application of clomazone in pre-emergence (Herb); and control without seed treatment and without pre-emergent herbicide (Test). Standak was used as insecticide for seed treatment (120 mL 100 kg^{-1} of seeds); as fungicide, Vitavax Thiram (300 mL 100 kg^{-1} seeds) was adopted.

For the experiment, the rice cv. Guri Inta CL was adopted. All seed treatments (factor B) were carried out three days before planting, effected on November 9, 2016, using a drill with 11 rows spaced in 0.17 m, with each plot of the experiment consisting of three drill passes, 5 m long each. The basic fertilization consisted on the application of 300 kg ha^{-1} of the formula 5-25-25, in the planting row. Topdressing fertilization consisted of two applications of 100 kg ha^{-1} of urea (45% N): beginning of tillering (December 9, 2016) and a few days before panicle initiation (January 13, 2017).

Irrigation was established on December 8, 2016, twenty days after plant emergence (DAE). In continuous irrigation, an average 7 cm of water was maintained during the experiment period, allowing variation from 10 to 5 cm; in the intermittent irrigation an initial 10 cm water layer was established, and then the water supply closed until the plot area was between 10 - 15% aerated (without water layer), when the 10 cm layer was again established.

Weed management was carried out with the application of clomazone in treatments C_Herb and I_Herb, and in the other treatments, only one application of the grass killer (inhibitor of the enzyme ACCase), registered and recommended for the crop, was used (Recommendations..., 2016).

Twelve days after planting, rice emergence was evaluated in four distinct rows of each plot, by counting all plants in 1 m. Live seedlings measuring more than 1 cm high were considered to be effectively emerged. Twenty DAE (beginning of irrigation and tillering), the average rice plant height was assessed, by measuring 10 plants per plot with a ruler. Thirty DAE (10 days after irrigation starts), the plant density was again measured, and four distinct row sections 1 m long were evaluated per plot, similarly to the first assessment. At the end of the crop cycle, rice grain yield was evaluated by harvesting 4 m^2 (4 x 1 m^2) per plot; the impurities were removed and then the yield was weighed and corrected to 13% moisture.

Data presentation was based on the 95% confidence intervals, according to Cumming et al. (2004). By this method, the comparison between treatments is done based on an expected response interval for similar cropping situations, and not based only on the responses of the treatments in the experiment. All analyzes were performed into the statistical environment "R".

Results and Discussion

The initial number of seedlings emerged twelve days after sowing (Figure 1) was approximately 160 per square meter, as the average of treatments. Although the confidence interval (95% confidence) showed no difference among treatments in soil-climatic conditions similar to those of the experiment, treatment with pre-emergence herbicide presented a smaller number of live plants twelve days after planting.

On the other side, seed treatment with insecticide alone had a higher number of live plants (faster emergence) compared to other treatments, but the confidence interval again reports that this difference may not be supported in field conditions similar to those of the experiment, because there was overlap in the confidence interval bars. Based on the 95% confidence intervals, the only difference was that seed treated with insecticides only performed better than those not treated and submitted to clomazone (Herb treatment) (Figure 1). A similar result occurred for the treatment with fungicide, in which a number of live plants were obtained close to that of the insecticide treatment (Figure 1).

For the average height of rice plants, no differences were observed between treatments (Figure 2), most likely because once emerged, the plants (or clomazone survivors) develop normally. If crop damage occurs as function of seed treatment, it may be due to lower plant establishment, with less impact on the growth of surviving seedlings. However, for cotton, it was observed that the higher doses of clomazone reduced plant stand and height (Silva and Santos, 2011). For rice, Concenço et al. (2006) also verified that the application of clomazone in doses higher than those indicated, combined with crop irrigation, caused a greater phytotoxicity to rice plants 19 DAE.

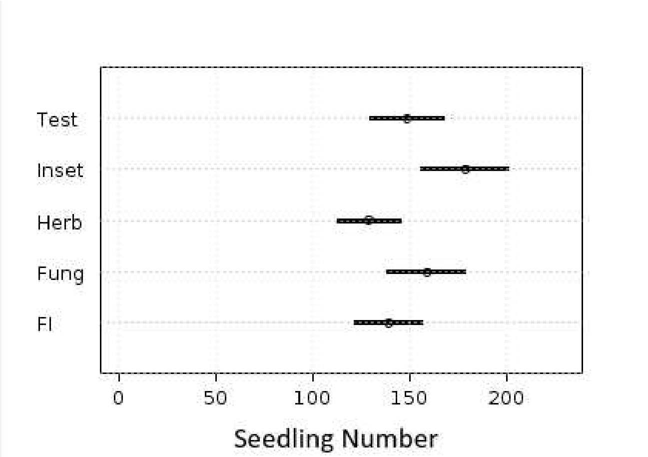

Figure 1: Number of plants emerged 12 days after planting, as function of seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and withouth pre-emergence herbicide. Confidence interval is presented (n=8). Irrigation management was not considered as it was yet to be applied to the fields at the time of the evaluation.

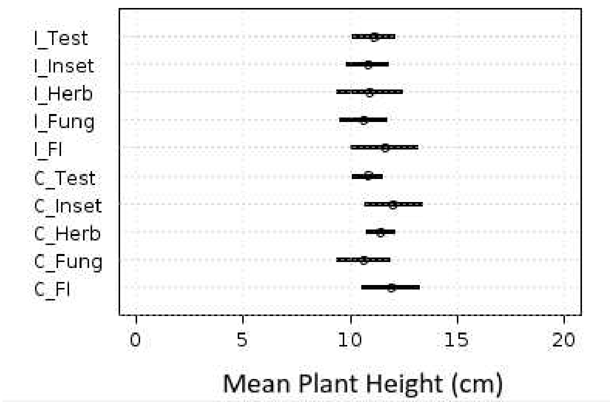

Figure 2: Rice plant height 20 days after emergence, as function of irrigation management (C_ = continuous; I_ = intermittent), and seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confidence interval is presented (n=10).

The number of plants at tillering start (Figure 3) varied between 320 and 430 plants m^{-2}, and the variation of the confidence intervals - due to the small number of samples per treatment (n = 4) for this variable, indicates that the values obtained in the experiment are not conclusive in relation to what could be observed in areas under similar soil and climatic conditions to those of the experiment, thus not allowing a clear differentiation between treatments.

The rice grains yield averaged 8000 kg ha^{-1} (Figure 4), but in field conditions it is possible to obtain productivity of up to 12000 kg ha^{-1} in some situations (95% confidence interval). It should be noted, however, that the number of samples contributed to the wide confidence intervals obtained and should not be considered as conclusive. Rice has compensatory capacity in its production components, counterbalancing some effects generated by the height of the water layer (ROSSO, 2014).

Barrigossi and Ferreira (2002), also treated seeds with insecticide, and between 20 and 25 days after planting they reported greater number of plants, mainly when used fipronil and furathiocarb, thiamethoxan, thiodicarb and carbosulfan were used, without productivity difference among treatments with insecticides. Almeida et al. (2014b), when treating seeds with thiamethoxam and lambdacyhalotrin, reported an increase in germination, especially when seeds were submitted to temperatures between 10 and 13 ºC. Thiamethoxan also optimized seed performance (Almeida et al., 2014a). In the treatment with the fungicide carboxim + thiram, Lobo (2008) verified that even though there was no blast (*Pyricularia grisea*) control under high pressure in the field, the fungicide helped optimizing seed emergence and performance.

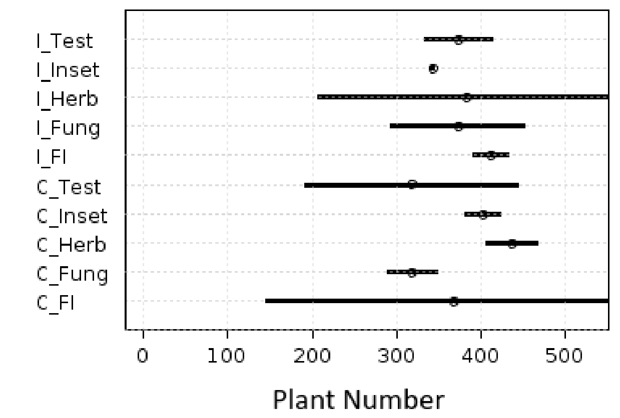

Figure 3: Number of rice plants 30 days after emergence, as function of irrigation management (C_ = continuous; I_ = intermittent), and seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confidence interval is presented (n=4).

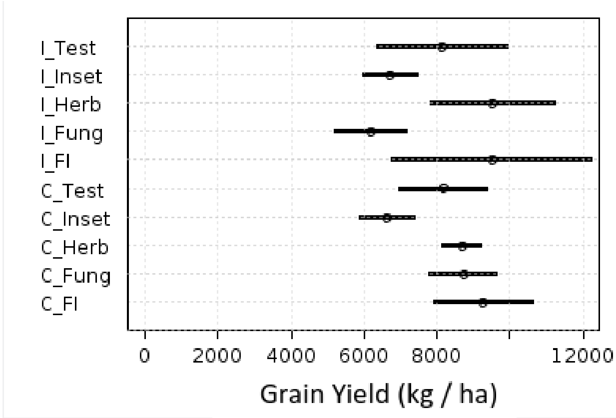

Figure 4: Rice grain yield cv. Guri Inta CL, corrected to 13% humidity, as function of irrigation management (C_ = continuous; I_ = intermittent), and seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confidence interval is presented (n=4).

Therefore, treatments that include the association of fungicides and insecticides seem to favor crop establishment (Brzezinski et al., 2015). In corn and wheat, the associated treatments did not affect the initial establishment of seedlings (Dartora et al., 2013), and there was increase in maize grains yield only with application of insecticide (Schlosser et al., 2012). In soybean, seed treatment with insecticides and fungicides helped to maintain the physiological and sanitary seed quality, providing benefits at different stages of growth and development, not reflecting, however, higher crop productivity (Cunha et al. 2015).

It should be emphasized that in none of the variables evaluated in the present study, there were any evidences that the differential water management could have affected the performance of the rice crop, since means and their respective confidence intervals were not different between treatments submitted to the continuous or to intermittent irrigation (Figures 1, 2, 3, 4).

The only observation that can be raised in this respect is that crop productivity showed higher confidence intervals - and therefore greater variability, in cropping situations similar to those of the experiment, under intermittent irrigation, which may require more attention from farmers to the correct water management, avoiding possible damages to the productivity - damages that were not observed in the present study. This corroborates with Santos et al. (2015), who reported that regardless of the irrigation method, rice yield remained unchanged.

Conclusions

There is neither evidence of differential seed treatment interference on the agronomic performance of rice, nor differences due to its interaction with irrigation management.

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Performance of Rice Crop as Function of Seed Treatment and Irrigation Method in Temperate Climate

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Introduction

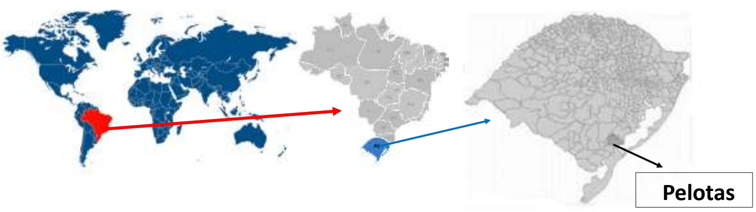
Seed treatment + **Safeners**

These same farmers raised the hypothesis that this possible negative interaction between products used in seed treatment may be linked to water management in the rice field.

Objective

Objectve of this work was to evaluate the performance of irrigated rice plants, as a function of seed treatment composition and crop irrigation management, in Brazilian Temperate Environment.

Material and Methods



Factors:

A: irrigation management
(continuous irrigation C_ / intermitent irrigation I_)

B: seed treatment composition
(fungicide and insecticide (FI); treatment with fungicide only (Fung); treatment with insecticide only (Inset)) application of clomazone in pre emergence (Herb)

Variety: rice cv. Guri Inta CL

Spacing: 0.17 m

Fertilization: 300 kg ha^{-1} of N-P-K 5-25-25 (basic fertilization);
100 kg ha^{-1} of urea (45% N) (topdressing fertilization consisted of two applications; V3-4 and R0)

Statistical Data presentation was based on 95% confidence intervals. All analyzes were performed into the statistical environment"R".

Results

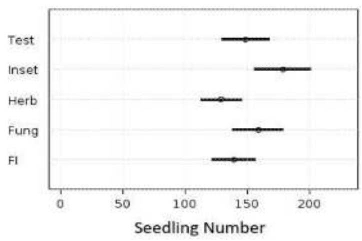


Figure 1: Number of plants emerged 12 days afer planting, as function of seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and withouth pre-emergence herbicide. Confdence interval is presented (n=8). Irrigation management was not considered as it was yet to be applied to the felds at the time of the evaluation

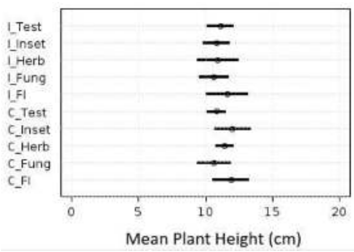


Figure 2: Rice plant height 20 days afer emergence, as function of irrigation management (C_ = contnuous; I_ = intermitent), and seed treatment as follows: Fung= fungicide; Herb= no treat. + preemergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confidence interval is presented (n=10).

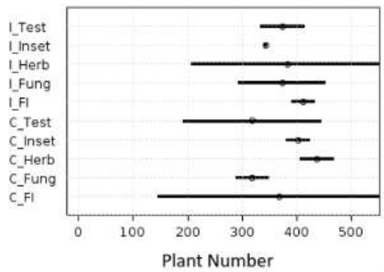


Figure 3: Number of rice plants 30 days afer emergence, as function of irrigation management (C_ = continuous; I_ = intermitent), and seed treatment as follows: Fung= fungicide;Herb= no treat. + pre-emergence herbicide; Inset= insectcide; FI= fungicide + insectcide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confdence interval is presented(n=4)

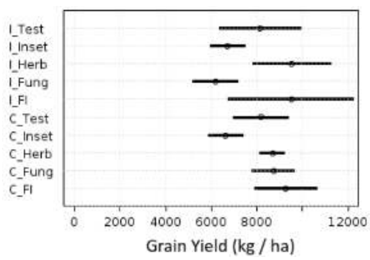


Figure 4: Rice grain yield cv. Guri Inta CL, corrected to 13% humidity, as functon of irrigation management (C_ = continuous; I_ = intermitent), and seed treatment as follows: Fung= fungicide; Herb= no treat. + pre-emergence herbicide; Inset= insecticide; FI= fungicide + insecticide; and Test= control treatment without seed treatment and without pre-emergence herbicide. Confidence interval is presented (n=4)

Conclusions

There is no evidence of deferential seed treatment interference on the agronomic performance of this crop, nor differences due to its interaction with irrigation management.

Cover Crop And Tillage Effect On The Weed Seed Bank In Lowlands

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Abstract

In irrigated rice fields, the most adapted weeds species appear in a high incidence in the cultivated paddies, which commonly have a highly populated weed seed-bank. In a long-term perspective, crop rotation is known as one of the most important management strategies to reduce the weed seed bank. In this sense, the objective of this work was to evaluate the dynamics of the weed seed bank of barnyardgrass (*Echinochloa sp*.) and alexandergrass (*Urochloa plantaginea*) in a lowland field, submitted to distinct crop rotation and soil management strategies. Irrigated rice, soybean and sorghum were cultivated under conventional- and no-tillage- soil management, in an experiment arranged in strips on the field. The seed bank of barnyardgrass and alexandergrass was evaluated after two years of cultivation, in the layers of 0-5 and 5-10 cm depth. The density of the seed bank was higher in sorghum compared to irrigated rice. There was no difference for the weed seed density between the soil layers, except for alexandergrass in monoculture of sorghum. This crop indeed increased the seed bank, and the evidences point that the reason for that was the lack of an effective post-emergence method of control (either herbicides or other method) of grass-weeds in sorghum.

Keywords: barnyardgrass, alexandergrass, monoculture, non-tillage, weeds.

Cover crop and tillage effect on the weed seed bank in lowlands

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Introduction

- In the monoculture of rice, the weed species more adapted to the production system appear in greater incidence in the area, being thus, the crop rotation can be alternative to help in the reduction of the weed seed bank.

Objective

- Evaluate the dynamics of the viable seeds bank of barnyardgrass and broadleaf-signalgrass in the lowlands, due to crop rotation and soil management.

Material and Methods

- Rice, soybean and sorghum crops were used under the management of conventional soil tillage (CST) and direct sowing system (DSS), cultivated in strips.

Table 1 – Treatments and respective soil tillage managements and crop rotations.

Treatment	Management	2015/16	2016/17	2017/18
1	DSS	Sorghum	Sorghum	Sorghum
2	DSS	Rice	Rice	Rice
3	DSS	Sorghum	Soybean	Sorghum
4	CST	Soybean	Soybean	Soybean
5	CST	Rice	Rice	Rice
6	CST	Soybean	Sorghum	Soybean

- It was evaluated the seed bank of barnyardgrass and broadleaf signalgrass after two years of cultivation, in the layer of 0-5 and 5-10 cm of depth

Results

Table 2- Contrasts of viable seed densities of barnyardgrass (m^{-2}) as a function of crop rotation and soil tillage management.

Contrast	Depth					
	0 – 5 cm			5 -10 cm		
C1	7002,82	x	1400,56*	1655,21	x	2291,83^{ns}
C2	7002,82	x	2928,45*	1655,21	x	2673,80^{ns}
C3	1400,56	x	1400,56^{ns}	2291,83	x	1273,24^{ns}
C4	1018,59	x	1400,56^{ns}	1400,56	x	1273,24^{ns}
C5	1018,59	x	2291,83^{ns}	1400,56	x	2164,50^{ns}

Table 3- Contrasts of densities of viable broadleaf-signalgrass seeds (m^{-2}) as a function of crop rotation and soil tillage management.

Contrast	Depth					
	0 – 5 cm			5 -10 cm		
C1	20753,80	x	636,62 *	2419,15	x	1145,92^{ns}
C2	20753,80	x	2546,48*	2419,15	x	1909,86^{ns}
C3	636,62	x	763,94^{ns}	1145,92	x	636,62^{ns}
C4	2673,80	x	763,94^{ns}	1273,24	x	636,62^{ns}
C5	2673,80	x	16679,44*	1273,24	x	14132,96*

Table 4- Density of viable seeds of barnyardgrass and broadleaf-signalgrass (m^{-2}), depending on crop rotation and soil tillage management, evaluated at different collection depths (0-5 and 5-10 cm).

Crop/Management	Barnyardgrass			Broadleaf-signalgrass		
	(0-5 cm) x (5-10 cm)			(0-5 cm) x (5-10 cm)		
Sorghum/DSS	7002,82	x	1655,21^{ns}	20753,80	x	2419,15*
Rice/DSS	1400,56	x	2291,83^{ns}	636,62	x	1145,92^{ns}
Sorghum/Soybean/DSS	2928,45	x	2673,80^{ns}	2546,48	x	1909,86^{ns}
Soybean/CST	1018,59	x	1400,56^{ns}	2673,80	x	1273,24^{ns}
Rice/CST	1400,56	x	1273,24^{ns}	763,94	x	636,62^{ns}
Soybean/Sorghum/CST	2291,83	x	2164,50^{ns}	16679,44	x	14132,96^{ns}

significant by t test ($p \leq 0.05$); ns not significant; C1 = Sorghum (DSS) x Rice (DSS); C2 = Sorghum (DSS) x Sorghum / Soy (DSS); C3 = Rice (DSS) x Rice (CST); C4 = Soy (CST) x Rice (CST); C5 = Soy (CST) x Soy / Sorghum (CST).

Conclusions

The density of the seed bank of barnyardgrass and broadleaf signalgrass were higher in sorghum monoculture compared to rice cultivation. There was no difference of the seed bank between different soil layers, except for the broadleaf signalgrass in monoculture sorghum. Sorghum monoculture, without post-emergence herbicide application, in the lowlands increases the seed bank of barnyardgrass and broadleaf signalgrass.

3 *Biotic stress / plant protection*

Upland Rice Production Residual Herbicide Overlay

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ABSTRACT

Rice (*Oryza sativa* L.) is grown in more than a hundred countries and is a major staple for nearly 2/3 of the world's population. In many areas of the world, rice is grown under upland conditions which produces lower yields compared with rice grown under flooded conditions. In addition to lower rice yields, weed spectrum can be altered due to the lack of weed control from flooding. A study was conducted in 2019 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate overlaying residual herbicides in upland rice production. Plot size was 3 by 11.3 m with sixteen, 19.5 cm drill-seeded rows of 'CLXL-729' at 39.2 kg ha^{-1}. The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of either no very early postemergence (VEPOST) application or a VEPOST application of a prepackaged mixture of imazethapyr plus quinclorac at 560 g ai ha^{-1} or imazethapyr at 70 g ai ha^{-1} mixed with either clomazone at 211 g ai ha^{-1}, pendimethalin at 1120 g ai ha^{-1}, a prepackaged mixture of clomazone plus pendimethalin at 717 g ai ha^{-1}, or a prepackaged mixture of halosulfuron plus prosulfuron at 83 g ai ha^{-1}. Factor B consisted of either no late postemergence (LPOST) application or a LPOST application of imazethapyr at 70 g ha^{-1} mixed with bispyribac at 34 g ai ha^{-1}. A uniform standard treatment of clomazone at 211 g ha^{-1} was applied preemergence. All postemergence applications were applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a backpack sprayer calibrated to deliver 93.5 L ha^{-1}. The results from this study suggest to overlay residual herbicides early in the growing season followed by a postemergence application later in the season.

Key words: Rice, Upland, Residual Herbicides, Weed Control.

Upland Rice Production Residual Herbicide Overlay

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Introduction

Rice (*Oryza sativa* L.) is grown in more than a hundred countries and is a major staple for nearly 2/3 of the world's population. Upland rice is a production system where rice is grown under a season long absence of a permanent flood. Upland rice acreage in Louisiana has increased from 570 hectares in 2017 to 6,240 hectares in 2019. The upland rice production system is gaining popularity in hopes of reducing water usage. However, water use can be similar to a conventional flooded system if numerus flushes are required in the absence of frequent rainfall (Golden and Roach 2019). Rice grown under upland conditions can result in a 10% decrease in yield compared with rice grown under flooded conditions (Hardke 2017). In addition to lower rice yields, weed infestations and spectrums can be altered due to the lack of cultural weed control that is obtained from a permanent flood. In the absence of a permanent flood it can be expected that weed seed germination will continue to occur throughout the duration of the growing season.

Objective

The objective of this study was to evaluate herbicide programs that incorporate overlaying residual herbicides in upland rice production.

Material and Methods

- This study was conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana in 2019 on a midland silty clay loam.
- The plot size was 3 by 11.3 m with sixteen, 19.5 cm drill-seeded rows of CLXL-729 at a seeding rate of 39 kg ha^{-1}.
- The research area was naturally infested with barnyardgrass [Echinochloa crus-galli (L.) P. Beauv.].
- The research area was either flushed or received weekly rainfall.
- Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}.
- Herbicides were applied at the very early POST (VEPOST) and late POST (LPOST) timings, which is equivalent to the spike- to two-leaf growth stage and the four- to five-leaf growth stage, respectively.
- Visual evaluations of percent control were recorded at 14 days after (DA) VEPOST and 21 DA LPOST for barnyardgrass.
- The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications.

Factor A		Factor B	
Herbicide	Rate (g ai ha^{-1})	Herbicide	Rate (g ai ha^{-1})
No VEPOST		No LPOST	
Imazethapyr + Clomazone	70, 211	Imazethapyr + Bispyribac	70, 34
Imazethapyr + Pendimethalin	70, 1120		
Imazethapyr + Clomzone + Pendimethalin[1]	70, 717		
Imazethapyr + Halosulfuron + Prosulfuron[2]	70, 83		
Imazethapyr + Quinclorac[3]	560		

[1]Prepackaged mixture of clomazone plus pendimethalin
[2]Prepackaged mixture of halosulfuron plus prosulfuron
[3]Prepackaged mixture of imazethapyr plus quinclorac

- A uniform standard treatment of clomazone was applied PRE at a rate of 211 g ai ha^{-1}.
- Data was subject to an ANOVA with a P value of 0.05.

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Results

Barnyardgrass

- At 21 DA LPOST, the prepackaged mixture of imazethapyr plus quinclorac and imazethapyr mixed with a prepackaged mixture of clomazone plus pendimethalin not followed by an LPOST application controlled barnyardgrass 75 and 76%, respectively. All of the other VEPOST treatments not followed by an LPOST application resulted in 45 to 64% control of barnyardgrass.
- All VEPOST treatments followed by an LPOST application controlled barnyardgrass 85 to 92% at the 21 DA LPOST rating date.
- The absence of a VEPOST treatment fb an LPOST application controlled barnyardgrass 57% at the 21 DA LPOST rating date.

Table 1. Barnyardgrass control at 14 DA VEPOST and 21 DA LPOST.

VEPOST Treatment	VEPOST fb No LPOST	VEPOST fb LPOST[1]
	14 DA VEPOST	
No VEPOST	0 f	18 e
Imazethapyr + Clomazone	82 a-d	84 a-d
Imazethapyr + Pendimethalin	78 bcd	74 cd
Imazethapyr + Clomzone + Pendimethalin[2]	87 ab	86 abc
Imazethapyr + Halosulfuron + Prosulfuron[3]	74 d	75 bcd
Imazethapyr + Quinclorac[4]	91 a	93 a
	21 DA LPOST	
No VEPOST	0 e	57 c
Imazethapyr + Clomazone	64 c	85 ab
Imazethapyr + Pendimethalin	63 c	88 a
Imazethapyr + Clomzone + Pendimethalin	76 b	90 a
Imazethapyr + Halosulfuron + Prosulfuron	45 d	88 a
Imazethapyr + Quinclorac	75 b	92 a

[1]LPOST: Imazethapyr mixed with bispyribac
[2]Prepackaged mixture of clomazone plus pendimethalin
[3]Prepackaged mixture of halosulfuron plus prosulfuron
[4]Prepackaged mixture of imazethapyr plus quinclorac

Photo 1. Clomazone fb No VEPOST fb Imazethapyr + Bispyribac

Photo 2. Clomazone fb Imazethapyr + Quinclorac fb No LPOST

Conclusion

A prepackaged mixture of imazethapyr plus quinclorac and imazethapyr mixed with a prepackaged mixture of clomazone plus pendimethalin applied VEPOST offers an extended period of residual control of barnyardgrass before an LPOST application is needed. Residual herbicides should be overlaid throughout the entire growing season, especially early in the season. In addition to overlaying early season residual herbicides, a third herbicide application will be needed around the four- to five- leaf growth stage to compensate for the loss of cultural weed control that is established with a permanent flood.

Herbicide Surface-Coated Urea for Aquatic Weed Control in Rice

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ABSTRACT

Louisiana rice is often produced in a rotation with crawfish production and often results in aquatic weed infestations. A study was conducted in 2019 at the Rice Research Station near Crowley, Louisiana to evaluate herbicides surface-coated onto granular urea fertilizer, 46-0-0, for control of 6 aquatic weed species. Weeds were collected, transplanted into 0.91 m^2 galvanized metal rings, and clipped 7 days prior to herbicide applications to ensure active growth. The treatments evaluated were: florpyrauxifen-benzyl at 29.3 g ai ha^{-1}, penoxsulam + florpyrauxifen-benzyl at 65 g ai ha^{-1}, and bensulfuron-methyl at 67 g ai ha^{-1}. The herbicides were surface-coated onto 112 kg ha^{-1} or 168 kg ha^{-1} of urea fertilizer. Herbicide-coated fertilizer was applied by hand into 6-cm flood with weed foliage submerged below the surface of the water to 25 cm above. At 10 days after treatment (DAT), *Heteranthera limosa* (Sw.) Willd. was controlled 60 to 68% with florpyauxifen; however, at 28 DAT *H. limosa* control was 97 to 99% when treated with florpyrauxifen with either rate of fertilizer. *Pontederia cordata* L. control was 65 to 73% at 10 DAT and 87 to 97% at 28 DAT when treated with a florpyrauxifen alone or plus penoxsulam. *Sagittaria graminea* Michx. control was 92 to 99% at 28 DAT when treated with all herbicide/fertilizer combinations evaluated. *Aeschynomene indica* L. and *Cyperus esculentus* L. control was less than 65% for all herbicide fertilizer combinations evaluated at 10 and 28 DAT. The control of *H. limosa* and the reduced control of *A. indica* and *C. esculentus* are likely due to the size of the weed above the waterline at the time of application.

Key words: florpyrauxifen-benzyl, aquatic weed control, herbicide surface-coated urea

Herbicide Surface-Coated Urea for Aquatic Weed Control in Rice

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Introduction

Aquatic weed infestations can be a major problem in Louisiana rice production due to the annual rotation between rice and crawfish. In 2018, florpyrauxifen was released commercially in the United States and showed activity on a number of different weed species. However, off-target movement of this herbicide caused concerns for neighboring soybean farmers. In Louisiana, the use of herbicide surface-coated or impregnated fertilizers is a common practice. This practice reduces the risk of off-target movement of the herbicide, and also allows for one less trip through the field for the grower by consolidating two applications. If florpyrauxifen activity is similar to a sprayed application, it could become another useful tool for the rice grower to fight aquatic weeds.

Objective

The objective of this study was to evaluate herbicides surface-coated onto granular urea fertilizer, 46-0-0, for control of five aquatic weed species.

Material and Methods

- A study was conducted in 2019 at the Rice Research Station near Crowley, Louisiana USA.
- This study was conducted as a randomized complete block with a two-factor factorial arrangement of treatments with three replications.
  - Factor A: 1) No herbicide. 2) florpyrauxifen @ 29 g ai ha^{-1}. 3) penoxsulam + florpyrauxifen @ 65 g ai ha^{-1}. 3) bensulfuron @ 67 g ai ha^{-1}.
  - Factor B: 1) No Urea. 2) Urea 46-0-0 @ 112 kg ha^{-1}. 3) Urea 46-0-0 @ 168 kg ha^{-1}. 4) Liquid application @ 140 L ha^{-1}.
- *Heteranthera limosa* (Sw.) Willd, *Pontederia cordata* L., *Sagittaria graminea* Michx., *Aeschynomene indica* L., *Cyperus esculentus* L. were collected, and transplanted into 0.91 m^2 galvanized metal rings.
- The herbicides were surface-coated onto urea, and applied by hand into a 6-cm flood with weed foliage submersed to 25-cm above the water.
- Visual control ratings for each weed species were taken at 10 and 28 days after treatment, and photos and biomass data were collected at 28 days after treatment.

Photo 1

Photo 2

Photo 3

Photo 4

Results

At 10 days after treatment (DAT), *H. limosa* was controlled 60 to 68% with florpyrauxifen at 112 and 168 kg ha^{-1}, respectively. However, at 28 DAT *H. limosa* control was 97 to 99% when treated with florpyrauxifen with either rate of fertilizer. *P. cordata* control was 65 to 73% at 10 DAT and 87 to 97% at 28 DAT when treated with a florpyrauxifen alone or plus penoxsulam. *S. graminea* control was 92 to 99% at 28 DAT when treated with all herbicide/fertilizer combinations evaluated. *A. indica* and *C. esculentus* control was less than 65% for all herbicide fertilizer combinations evaluated at 10 and 28 DAT.

Table 1. % Control and Biomass in grams for Herbicide Impregnated Urea

Treatment	H. limosa			P. cordata			S. graminea			A. indica			C. esculentus		
	10 DAT	28 DAT	Biomass	10 DAT	28 DAT	Biomass	10 DAT	28 DAT	Biomass	10 DAT	28 DAT	Biomass	10 DAT	28 DAT	Biomass
Nontreated	0 e	0 d	2761b	0 d	0 c	52b	0 c	0 d	24a	0 d	0 d	202a	0 e	0 d	155a
florpyrauxifen @ 112 kg ha^{-1} Urea	65bc	98a	0c	65 ab	87a	16c	55 ab	97ab	2 bc	33c	63b	84bcd	22b	17c	153a
florpyrauxifen @ 168 kg ha^{-1} Urea	65bc	98a	0c	65 ab	93a	7 c	65a	97ab	0 c	20 cd	30c	72bcd	25 bc	17c	130ab
penoxsulam + florpyrauxifen @ 112 kg ha-1 Urea	68b	99a	0c	65 ab	99a	0 c	72a	98a	0 c	37c	63b	34cd	38b	40b	79abc
penoxsulam + florpyrauxifen @ 168 kg ha-1 Urea	60c	97a	0c	73 a	98a	0 c	70a	98a	1bc	17 cd	43c	77bcd	30b	27 bc	99abc
bensulfuron @ 112 kg ha-1 Urea	0 e	18c	3480ab	38 bc	92a	6 c	37b	94bc	2bc	0 d	12d	152ab	0 e	20c	50bc
bensulfuron @ 168 kg ha-1 Urea	0 e	22c	4102a	45abc	67b	16c	53 ab	93c	10bc	0 d	28c	106bc	0 e	22c	127ab
florpyrauxifen + MSO	97a	99a	0c	57abc	97a	4 c	68a	99a	0 c	98a	99a	0d	58a	73a	43c
penoxsulam + florpyrauxifen + MSO	98a	99a	0c	60abc	91a	18c	62 ab	99a	0 c	98a	99a	0d	60a	77a	44c
bensulfuron + COC	30d	57b	2895b	32 cd	53b	74a	57 ab	92c	15ab	63b	42c	72bcd	10 cd	37b	127ab

Photo 5

Photo 6

Photo 7

Photo 8

(Photo 1): Nontreated; (Photo 2): florpyrauxifen on urea @ 112 kg ha^{-1};(Photo 3): florpyrauxifen on urea @ 168 kg ha^{-1}; (Photo 4): florpyrauxifen + MSO @ 140 L ha^{-1}; (Photo 5): penoxsulam + florpyrauxifen on urea @ 112 kg ha^{-1}; (Photo 6): penoxsulam + florpyrauxifen on urea @ 168 kg ha^{-1}; (Photo 7): penoxsulam + florpyrauxifen + MSO @ 140 L ha^{-1}; (Photo 8): bensulfuron on urea @ 168 kg ha^{-1}.

Conclusions

Although herbicides surface-coated onto urea work much slower than herbicides broadcast as a spray solution, they may have a fit for controlling aquatic weeds in Louisiana rice. The control of *H. limosa* and the reduced control of *A. indica* and *C. esculentus* are likely due to the size of the weed above the waterline at the time of application.

NEW STRATIGIES FOR THE MANAGEMENT OF MAJOR RICE DISEASES IN GUYANA.

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Abstract

In Guyana, the rice industry is one of the most important agricultural industries and attracts more than US$ 200 million annually, which amount to approximately 10% of the country's earning. The rice crop known to be affected by many diseases of which rice blast (*P. oryzae*); Sheath blight (*R. solani)* and rice grain discolouration (*C. lunata*) are three of the major disease threatens Guyana rice industry. Studies were carried out in Guyana (i) to identify blast and sheath blight resistant and slow blighting germplasm, (ii) to study the efficacy of botanicals, bioagents and new generation fungicides against blast and sheath blight (SB) diseases as well as, (iii) to identify the cause agent and to develop strategies for managing rice grain discolouration. Of 103 rice germplasm lines, 11 showed highly resistant to resistant reactions to blast. Genotype FL-127 consistently expressed high blast resistance. Of the 101 genotypes evaluated against SB, genotypes FG12-56 and GR1631-35-16-1-2-1-1 recorded immune to resistant reactions, consistently. Twelve genotypes exhibited very resistant to resistant reactions. The botanicals, bioagents and new generation fungicides were evaluated against blast and SB. The extracts of Black sage at 10%, Bael at 15% and Madar plant at 5% reduced blast infection in field experiments; Likewise Lemon grass and Thick leaf thyme at 15% reduced SB under screenhouse and field conditions. The bioagent, *Bacillus cereus* OG2L and *B. subtilis* OG2A significantly reduced blast; while *B. cereus* OG2L effectively reduced SB. The new generation fungicides, Antracol 70WP and

Nativo 75 WG, showed superior control against blast; while the same fungicides along with Serenade 1.34 SC effectively reduced SB. The treatments found to be effective in disease control also showed positive influence on growth and yield of rice. In a separate experiment the initial analysis of samples revealed the presence of *Curvularia* spp., *Bipolaris oryzae*, *Scarladium oryzae*, *Alternaria* spp., *Aspergillus* spp. and *Fusariun* spp. on rice grains with discolouration symptoms with *Curvularia lunata* was observed as the most predominant organism in 95% of the samples. Similarly, the application of Amistar Xtra 28 SC at 1.5 ml/L; Glory 75 WG at 3.0 g/L; Antracol 70WP at 5.0 g/L and Carbendazim 50SC at 1.5 ml/L showed significant reduction in incidence of grain discolouration ranged from 48.58 to 92.85% and unfilled grains per panicle. Also, these fungicide treatment demonstrated higher number of filled grains per panicle, 1000- grain weight and over all grain yields as compared to the untreated control treatment.

Keywords: rice disease management; blast; sheath blight; grain discolouration resistant**;** plant products; bioagents; new generation fungicides.

Improving Monitoring and Management of Armyworms in California Rice

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ABSTRACT

After a severe true armyworm outbreak in the rice production area of the Sacramento Valley of California, several studies were conducted to improve management of the pest. Pheromone trapping showed that moth catches could be used to better inform monitoring timing. In an artificial defoliation trial, effects on plant height, panicle development, and yield, were only observed when defoliation was 100% of foliage above the water during mid tillering. Finally, an insecticide trial found products that could be used to manage armyworms effectively.

Key words: armyworms, *Mythimna unipuncta,* pheromone traps

1. Introduction

Armyworms have been considered a secondary pest in California rice. Typically, larvae can be found during mid tillering and the heading stage. Two species have been documented feeding in rice, the true armyworm (*Mythimna unipuncta*) and western yellowstriped armyworm (*Spodoptera praefica*) (Strand, 2013). Outbreaks have occurred in the past, but they have not been severe according to those working in the industry for more than 25 years. In late June 2015, a true armyworm outbreak occurred, causing severe defoliation during mid tillering. Several fields suffered yield losses. Since 2015, armyworm levels have remained high, with 2017 being a severe armyworm year again.

Armyworm monitoring is challenging. Moths fly at night, and their eggs are rarely found in rice or surrounding vegetation. Small armyworms are difficult to find and scouting for larger larvae is physically demanding and time consuming. Thresholds for armyworm insecticide applications were developed in California during the late 1970s (Rice et al., 1982). The threshold for mid season infestations recommends an insecticide application only if defoliation is larger than 25% and larvae are still present in the field. Because of fast larval development during the summer months, defoliation can increase very quickly, making determining the correct timing of treatments difficult.

Several projects were conducted in 2018 and 2019 to improve the monitoring and management of armyworms with insecticides. These consisted in adult armyworm pheromone trapping, and defoliation and insecticide trials.

2. Materials and Methods

2.1. Armyworm pheromone trapping

Pheromone traps for the true armyworm and western yellowstriped armyworm were placed in rice field levees in 15 locations across the rice production area of the Sacramento Valley. Each trap consisted of a bucket trap, a lure, and a killing agent inside the bucket. Lures were changed every two weeks and the killing agent every four weeks. In each location, three traps were placed per species. Moths were counted weekly from seeding until grain maturity, when rice is not at risk of armyworm injury. In 2019, in three of the 15 locations, weekly armyworm searchers were conducted.

2.2. Defoliation trial

The trial was set up in field seeded with variety M-206 at a seed density of 150 lbs/a in Butte County. Plots 3x3 m were subjected to four defoliation treatments: 0, 25, 50, or 100% of plant height above the water level. When plants reached the second tiller stage, defoliation treatments were started. To defoliate plants, 25% of foliage height was cut per day in the whole plot using hedge shears. Leaf residue was raked outside of the plots. Water depth during the time defoliation treatments were applied was 4 inches. Plant height was measured at different times during crop development and before harvest. Proportion of panicle emergence per plot was recorded weekly during heading. Plots were harvested with a small plot combine and yields transformed to 14% MC. The experiment was conducted as a randomized complete block with six replications. Parameters evaluated were analyzed using ANOVA and treatment means compared using Tukey's test (α = 0.05).

2.3. Insecticide trial

Several insecticides were tested for armyworm control in a commercial rice field in Butte County. Plots 3x6 m were established in an area of rice field, variety M-206, where armyworms and defoliation was observed. Armyworm density was determined by counting larvae/0.09 m^2 on four, 0.09 m^2 quadrants in each plot. Each armyworm search lasted 1.5 min. Larvae were collected for identification and instar determination. Treatments were applied at mid tillering using a CO_2-powered backpack sprayer. Armyworm populations were evaluated before treatments were made and 3, 5, and 7 days after the applications. The trial was established as a randomized complete block with three replications. Number of live larvae/0.09 m^2 was analyzed using ANOVA and treatment means compared to the untreated means using contrasts. The level of α used was 0.05.

3. Results and Discussion

3.1. Armyworm pheromone trapping

In 2018 and 2019, armyworm pressure was similar. In the field, only true armyworm larvae was observed causing defoliation. Averaging all locations, true armyworm moth numbers began to increase in early June, and peaked near July 1st (fig. 1). A second and smaller peak occurred early to mid August. Both peaks timing coincided with the timing when the most larvae activity was observed in the field. Compared with 2018, moth numbers in 2019 peaked about a week later. Overall, number of moths per trap was similar in both years. Western yellowstriped armyworm moth numbers were very low during 2018, and peaked to 30 moths/trap/day during mid May in 2019; however, during both years, western yellowstriped armyworm larvae were not found in rice fields in any significant numbers.

Experience from two years of pheromone trapping indicates that fields that have low catches (around 30 or less) do not experience severe defoliation. When moth catches are high, defoliation may or may not be severe. Rice fields have several natural enemies (insects, spiders, birds) that can reduce the population of larvae, especially during the early instars. If those natural enemies are effective, larvae may not make it to the later stages.

In the field, pheromone traps can be used to monitor armyworm activity. When moth numbers are low, the risk of armyworm damage is low. When moth numbers are high, monitoring needs to be increased to timely detect defoliation and larvae in the field. Best timing for treatments seems to coincide with when the moth peak is reached. However, this determination can only be made after the peak has passed because traps are checked weekly. More frequent trap monitoring could improve detection of the peak. Other trap types, such as automatic traps that record numbers caught daily could also be used to better time scouting and treatment needs.

3.2. Defoliation trial

At each evaluation date after defoliation, the treatments had a significant effect on plant height (P<0.001). On all dates, plots defoliated 100% had significantly shorter plants than the rest of the plots. Plant height from plots defoliated 25 or 50% or not defoliated did not differ significantly. Before harvest, plots defoliated to the water line were 80 cm in height, 20 cm shorter than all other treatments.

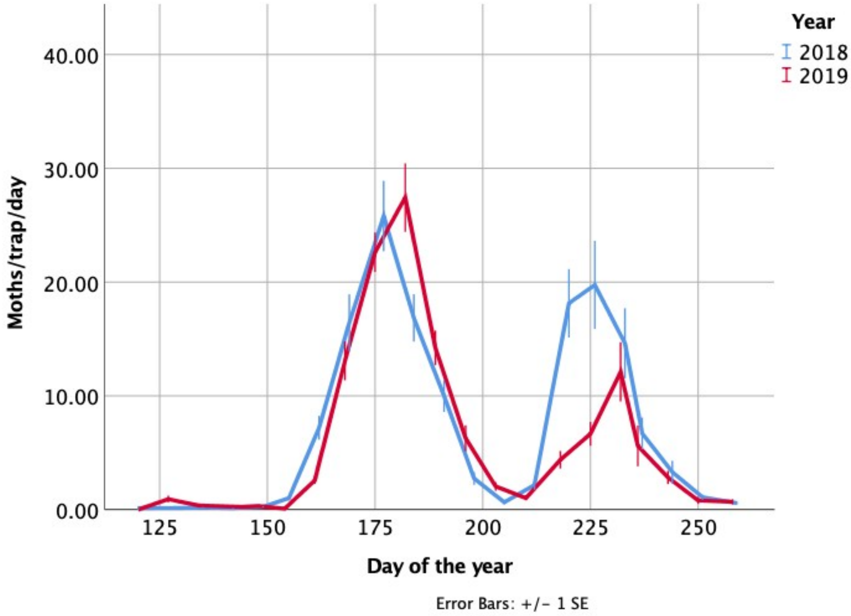

Fig. 1. Average number of true armyworm moths caught in pheromone traps at 15 rice fields in the Sacramento Valley of California in 2018 and 2019.

Panicle emergence per plot at each evaluation date was significantly affected by the treatments (P<0.001). In all evaluation dates, plots defoliated 100% had significantly lower proportion of panicles emerged than plots not defoliated, or plots defoliated 25 or 50%. Percentage heading reached 100% in plots defoliated 100% 12 days later than all other treatments. Yields were significantly affected by the defoliation treatments (P<0.001). Plots defoliated to the water line had a significantly lower yield (6,304 kg/ha) than plots under all the other treatments (8,581 kg/ha).

3.3. Insecticide trial

All larvae collected (13) were identified as true armyworm. Most (77%) of the larvae collected were at the 6th instar. At the time treatments were made, plots averaged 3.2 larvae/0.09 m^2 (table 1). After treatments, armyworm density in all plots, including the untreated plots, declined with time. Two factors explain this; one is the fact that most larvae were at the 6th instar, so some of them may have completed their cycle and pupated. The second factor is the presence of a disease that affected the larvae. Many larvae, even in untreated plots, showed necrotic spots and some hanged from leaves, as larvae affected by diseases typically do.

Three days after application, the treatments did not have a significant effect on the number of larvae/0.09 m^2. However, Coragen reduced the number of worms by more than 50%. Five days after treatment, Intrepid and Coragen resulted in significantly (P=0.031) fewer larvae/0.09m^2 than the untreated plots. These two treatments reduced larval density by 87 and 62%, respectively. At the end of the experiment, all products resulted in a significant (P=0.007) reduction in the numbers of larvae/0.09 m^2, with Intrepid, Coragen and Prevathon giving the best levels of control.

4. Conclusions

Pheromone traps could be used to improve monitoring of armyworms in rice in California. Because injury occurs fast, moth trapping could inform growers when monitoring efforts need to be increased. Trapping data could be supplemented with developmental models to predict when most of the injury will occur.

Artificial defoliation of rice caused a yield reduction only when it was very severe. Information developed earlier established that 25% armyworm defoliation could result in a yield reduction. Given that the varieties currently being used are different from the ones used to develop the threshold, more work to refine the thresholds is needed.

The insecticide trial conducted showed that there are options for good armyworm control; however, two of the most effective insecticides (Intrepid and Prevathon) do not have full registrations yet. Work should continue to identify other products that could be used for armyworm control.

Table 1. Number of armyworm larvae/0.09m^2 in an insecticide trial for armyworm control, Butte County, 2019.

Treatment (a.i.)	Rate/ha	0 DAT[1]	3 DAT	5 DAT	7 DAT	% reduction
Untreated	--	3.00	2.17	1.33	1.17	--
Dimilin 2L (diflubenzuron)	586 ml	2.83	1.58	1.42	0.25*	78.63
Intrepid 2F (methoxyfenozide)	732 ml	2.08	1.17	0.17*	0.00*	100
Warrior II (lambda-cyhalothrin)	187 ml	3.42	1.33	1.67	0.33*	71.79
Prevathon (chlorantraniliprole)	1024.8 ml	4.92*	2.33	0.83	0.00*	100
Spear-Lep + DiPel (GS-omega/kappa-Hxtx-Hv1a + *Bt* sp. kurstaki)	946 ml + 454 g	3.83	1.50	1.00	0.50*	57.26
DiPel (*Bt* sp. kurstaki)	454 g	2.75	1.50	1.00	0.25*	78.63
Coragen (chlorantraniliprole)	256 ml	2.67	0.92	0.50*	0.08*	93.16

[1]DAT=Days after treatment

Means followed by * were significantly different than the untreated mean (P<0.05)

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Improving Monitoring and Management of Armyworms in California Rice

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Introduction

In 2015, rice in California experienced a true armyworm (*Pseudaletia unipuncta*) outbreak. Severe defoliation and yield losses were observed in many areas. Since then, armyworm levels have remained high and insecticide treatments for control have become more common.

Objectives

Studies were conducted during 2018 and 2019 to:

- Explore the use of pheromone traps to improve armyworm monitoring
- Determine the effect of armyworm defoliation on rice growth and yield
- Identify insecticides for armyworm control

Materials and Methods

1. Pheromone traps for armyworm monitoring

Three traps per field were set up in 15 commercial fields across the Sacramento Valley. Each trap was checked weekly and lures changed every two weeks.

2. Defoliation trial

Plots 9.2 m^2 were assigned four levels of defoliation, 0, 25, 50, and 100% of plant height above the water level. Plots were defoliated starting at the mid tillering stage 25% of plant height per day. Plant height, percent heading (panicle emergence), and yield were evaluated. Defoliation treatments were replicated six times.

3. Insecticide trial

Number of armyworms in plots 18.9 m^2 was determined before and after treatment with registered and experimental insecticides. Treatments were replicated three times.

Results

1. Pheromone traps for monitoring adult flight

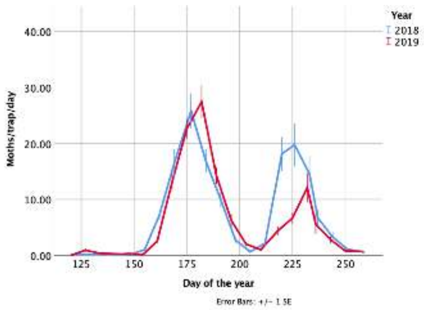

Fig. 1. Average number of moths caught daily from May through September in 15 commercial rice fields across the Sacramento Valley of California. Day 125=5 May

- Peak moth trapping in late June (day 175) coincided with when most larvae activity was observed in the field.
- Peak moth trapping in mid August (day 225) coincided with when damage to the panicle is observed in the field.
- Fields with low catches (below 30 moths/trap/day or less) did not experience severe defoliation.
- In fields with high number of catches, defoliation was not always severe.

Results

2. Defoliation trial

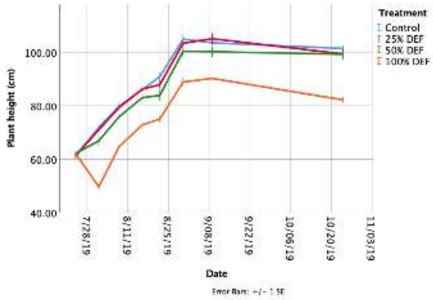

Fig. 2. Plant height under four defoliation (DEF) treatments. Only the 100% defoliation level resulted in a significant (P<0.05) reduction of plant height.

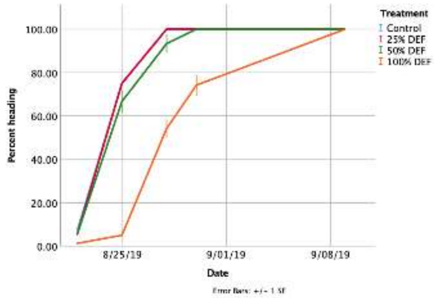

Fig. 3. Percentage of plants headed per plot under four defoliation (DEF) treatments. Heading in plants defoliated 100% was delayed 12 days compared to the rest of treatments.

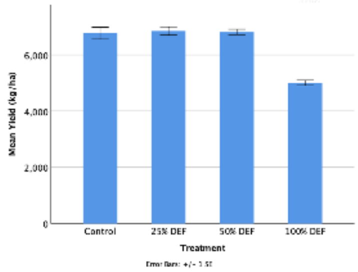

Fig. 4. Yield under four defoliation (DEF) treatments. Only yields from plots defoliated 100% to the water level were significantly (P<0.05) lower than yields from other defoliation treatments.

3. Insecticide trial

Table 1. Average number of armyworm larvae/0.09 m^2

Treatment (a.i.)	Rate/ha	0 DAT[1]	3 DAT	5 DAT	7 DAT	% reduction
Untreated	--	3.00	2.17	1.33	1.17	--
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Coragen (chlorantraniliprole)	256 ml	2.67	0.92	0.50*	0.08*	93.16

[1]DAT = days after treatment *Significantly different from the untreated (P<0.05)

Conclusions

- True armyworm pheromone trapping could be used to alert growers when to increase field monitoring to avoid severe defoliation.
- Defoliation to the water level resulted in shorter plants, delayed heading, and lower yields. Economic thresholds for armyworm defoliation injury need to be revised.
- Good options for armyworm control were identified; however, two of the most effective insecticides (Intrepid and Prevathon) do not have full registrations yet.

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USE AND MANAGEMENT OF ACCASE-RESISTANT RICE TECHNOLOGY IN THE UNITED STATES

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Abstract

A current weed management issue in rice-producing areas throughout the world is the management of weedy rice (Oryza sativa L.), more particularly, imidazolinone-resistant (IR) weedy rice. With concerns around IR weedy rice resistance, BASF developed a new herbicide-resistant rice sold under the trade name Provisia®. The herbicide targeted for use is quizalofop, which will also be sold under the trade name Provisia®. Quizalofop is a Group 1 herbicide, which inhibits the acetyl-coA carboxylase (ACCase) enzyme. A study was conducted at the RRS to evaluate the activity of quizalofop applied independently or in a mixture with herbicides with the ALS mode of action or contact activity. Plot size was 5.1 by 2.2 m, with eight 19.5-cm-wide drill-seeded rows. Antagonistic responses were observed for red rice control at 14 DAIT when quizalofop was mixed with bispyribac or penoxsulam plus triclopyr. All other mixtures resulted in a neutral response on red rice at 14 DAIT. However, at 28 DAIT, all mixture herbicides evaluated antagonized quizalofop for red rice control. Penoxsulam, penoxsulam plus triclopyr, or bispyribac mixed with quizalofop reduced the expected control of 97% to an observed control of 59% to 67%. Halosulfuron, orthosulfamuron plus halosulfuron, orthosulfamuron plus quinclorac, imazosulfuron, or bensulfuron mixed with quizalofop reduced red rice control to an observed control of to 81 to 88%. Antagonistic responses were observed for red rice control when quizalofop was mixed with propanil at 14, 28, and 42 DAIT. At 42 DAIT, a slightly antagonistic response was indicated for red rice treated with quizalofop plus propanil. All other contact herbicides mixed with quizalofop resulted in a neutral response for red rice control at all evaluation dates, indicating the potential as mix partners with quizalofop for red rice control in ACCase-R rice production.

KEYWORDS: quizalofop, *Oryza sativa* L., herbicide resistant rice

1. Introduction

A current weed management issue in rice-producing areas throughout the world is the management of weedy rice, more particularly, imidazolinone-resistant (IR) weedy rice (Rustom et al. 2018). IR rice technology, first commercialized in 2002, allowed producers to control red rice with a herbicide during cultivated rice production for the very first time (Webster et al. 2017). Weedy rice is taxonomically classified as the same species as cultivated rice but can include different phenotypic characteristics, such as various grain colors, medium-to-long grain size, awned or awnless seeds, light to dark green vegetation color, variable plant height, and pubescent to glabrous leaves (Rustom et al. 2018, 2019). Weedy rice has greater height and tillering capabilities than does cultivated rice; therefore, it can compete for nutrients and light at a higher rate than cultivated rice.

IR hybrid rice seed has dormancy characteristics, and if these seed are allowed to germinate, emerge, and establish, the plants can become a weed in future growing seasons (Rustom et al. 2018). These offspring can segregate which can cause a serious weed problem with many different phenotypes, and can potentially be IR. Outcrossing between cultivated rice and its weedy and wild relatives has also been observed. Research has suggested that the technology used in IR rice can be transferred by natural outcrossing to produce IR red rice. The term weedy rice will refer to the entire complex of volunteer hybrids, outcrosses, and red rice.

Another weed management issue in rice-producing areas throughout the world is barnyardgrass. Barnyardgrass competing for nutrients and light can result in significant cultivated rice yield reductions. Barnyardgrass resistant to imazethapyr and imazamox has become a common issue in rice production throughout the southern United States, which further reduces the usefulness of IR rice. Historically, weed control programs in rice in the southern United States have included propanil for the control of annual grasses such as barnyardgrass. Propanil resistant barnyardgrass and other herbicide resistant weed biotypes have the potential to spread, and resistant biotypes must be managed to prevent future issues (Osterholt et al. 2019).

With rising concerns about IR weedy rice and barnyardgrass resistant to herbicides with different modes of action, BASF developed a new herbicide-resistant rice to be sold under the trade name Provisia®. The herbicide targeted for use is quizalofop, which will also be sold under the trade name Provisia® (Anonymous 2017). Quizalofop is a Group 1 herbicide, with a mode of action that inhibits acetyl-coA carboxylase enzyme. Quizalofop provides postemergence control of annual and perennial grasses with little to no activity on broadleaf weeds and sedges (Rustom Et al 2018, 2019). Quizalofop has been used to substantially reduce weedy rice infestations during soybean production and noncrop areas for annual or perennial grass control. The targeted single quizalofop application rate in ACCase-resistant (ACCase-R) rice production will be 92 to 155 g ha^{-1}, not to exceed 240 g ha^{-1} yr^{-1}.

2. Material and Methods

A study was conducted in 2015 and 2016 at the H. Rouse Caffey Rice Research Station (RRS) near Crowley, Louisiana to evaluate the activity of quizalofop applied independently or in a mixture with herbicides with the ALS mode of action or contact activity. The soil type at the RRS is a Crowley silt loam with a pH of 6.4 and 1.4% organic matter. Plot size was 5.1 by 2.2 m, with eight 19.5-cm-wide drill-seeded rows planted as follows: four center rows of ACCase-R ‘PVL024B’ long grain rice, two rows of IR ‘CL-111’ long grain rice, and two rows of IR ‘CLXL-745’ hybrid long grain rice. Rice was planted at a rate of 67 kg ha^{-1}. Awnless strawhull red rice was broadcast in the plot area prior to drill seeding at a rate of 50 kg ha^{-1}. The IR rice line, IR hybrid, and red rice were planted to represent a weedy rice population. The research area was naturally infested with barnyardgrass.

Each herbicide application was applied when ACCase-R rice was at the three- to four-leaf growth stage. Red rice, CL-111, and CLXL-745 were at the three- to four-leaf growth stage and barnyardgrass was at the two- to five-leaf growth stage with a population of 50 to 100 plants m^2 when the applications were applied. The study was a randomized complete block with a factorial arrangement of treatments with four replications. For the ALS study, factor A consisted of quizalofop applied at 120 g ha^{-1} or no quizalofop. Factor B consisted of penoxsulam at 40 g ai ha^{-1}, penoxsulam plus triclopyr at 352 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, bispyribac at 34 g ai ha^{-1}, orthosulfamuron plus halosulfuron at 94 g ai ha^{-1}, orthosulfamuron plus quinclorac at 491 g ai ha^{-1}, imazosulfuron at 211 g ai ha^{-1}, bensulfuron at 43 g ai ha^{-1}, or no mixture herbicide. In the contact study, factor A was quizalofop applied at 120 g ha^{-1} or no quizalofop (Table 1). Factor B was bentazon at 1050 g ai ha^{-1}, carfentrazone at 18 g ai ha^{-1}, propanil at 3360 g ai ha^{-1}, saflufenacil at 25 g ai ha^{-1}, thiobencarb at 3360 g ai ha^{-1}, or no mixture herbicide. A second quizalofop application was applied to all treatments at a rate of 120 g ha^{-1} at 28 days after the initial quizalofop treatment (DAIT). This application was applied to evaluate quizalofop efficacy on weedy rice and barnyardgrass that escaped the initial application, potentially as a result of antagonism, and because it is recommended by the BASF stewardship program for managing resistance development for ACCase-R (Anonymous 2017). A crop oil concentrate was added to each herbicide application at a rate of 1% v v^{-1} except treatments containing thiobencarb or propanil.

A field study was established in 2013 to evaluate long-term rotations for control of weedy rice plants. The long-term rotation field is located near Esterwood, Louisiana with a similar soil type as the RRS. The field has a large population of both hybrid rice dormancy issues and possible red rice out-crosses with IR rice. The plants present have a red rice appearance from a distance, but closer evaluation indicates both smooth and pubescent leaf surfaces, pale green to dark-green to purple vegetation, and long- and medium-grain rice. It is apparent the field was close to being a total failure with a loss of profitability due to weedy rice competition and possible need for abandonment. The four-year rotation study evaluated five rotations including the use of Provisia rice in 2014. The rotations used are: **Rotation 1)** glyphosate-resistant (GR) soybeans (2013) followed by (fb) ACCase-R rice (2014) fb GR soybeans (2015) fb IR hybrid rice (2016); **Rotation 2)** Fallow (2013) fb ACCase-R rice (2014) fb GR soybeans (2015) fb IR hybrid rice (2016); **Rotation 3)** IR hybrid rice (2013) fb glufosinate-resistant (Glu-R) soybeans (2014) fb ACCase-R rice (2015) fb IR hybrid rice (2016); **Rotation 4)** GR soybeans (2013) fb Glu-R soybeans (2014) fb GR soybeans (2015) fb IR hybrid rice (2016); **Rotation 5)** GR soybeans (2013) fb IR hybrid rice (2014) fb GR soybeans (2015) fb IR hybrid rice (2016).

3. Results and Discussion

3.1. ALS Mixture Study. Antagonistic responses were observed for red rice control at 14 DAIT when quizalofop was mixed with bispyribac or penoxsulam plus triclopyr. All other mixtures resulted in a neutral response on red rice at 14 DAIT. However, at 28 DAIT, all mixture herbicides evaluated antagonized quizalofop for red rice control. Penoxsulam, penoxsulam plus triclopyr, or bispyribac mixed with quizalofop reduced the expected control of 97% to an observed control of 59% to 67%. Halosulfuron, orthosulfamuron plus halosulfuron, orthosulfamuron plus quinclorac, imazosulfuron, or bensulfuron mixed with quizalofop reduced red rice control to an observed control of to 81% to 88%. Hybrid CLXL-745 rice was also treated with all mixtures evaluated for red rice control. At 14 DAIT, the addition of bispyribac or penoxsulam plus triclopyr antagonized quizalofop; however, the addition of penoxsulam alone, halosulfuron, or orthosulfamuron plus quinclorac also antagonized quizalofop on CLXL-745. All ALS herbicides mixed with quizalofop proved to antagonize quizalofop on CLXL-745 at 28 DAIT. Antagonistic responses were observed at 14 DAIT for CL-111 when treated with quizalofop plus any ALS herbicide except bensulfuron, which indicated a neutral response. Bensulfuron was the only ALS herbicide that did not antagonize quizalofop activity on red rice, CLXL-745, or CL-111 evaluated at 14 DAIT, and this may indicate the potential as a mixture herbicide with quizalofop early in the growing season when weedy rice is present. At 14 DAIT, bispyribac and penoxsulam plus triclopyr antagonized quizalofop for barnyardgrass, red rice, CLXL-745, and CL-111 control. In addition, penoxsulam, orthosulfamuron plus halosulfuron, and orthosulfamuron plus quinclorac were also found to be antagonistic for barnyardgrass control at 14 DAIT. Any antagonism observed at 14 and 28 DAIT was overcome with a second application of quizalofop, except with penoxsulam-containing herbicides for barnyardgrass control.

3.2. Contact Mixture Study. Antagonistic responses were observed for red rice control when quizalofop was mixed with propanil at 14, 28, and 42 DAIT. At 42 DAIT, a slightly antagonistic response was indicated for red rice treated with quizalofop plus propanil. All other contact herbicides mixed with quizalofop resulted in a neutral response for red rice control at all evaluation dates, indicating the potential as mix partners with quizalofop for red rice control in ACCase-R rice production. Antagonistic mixtures for CLXL-745 control included quizalofop mixed with propanil, bentazon or saflufenacil at 14 DAIT. CL-111 responses were similar to CLXL-745, except a neutral response was observed for quizalofop mixed with saflufenacil at 14 DAIT. Similar to red rice, CLXL-745, and CL-111, propanil antagonized quizalofop activity on barnyardgrass at 14 and 28 DAIT. By 42 DAIT, the second quizalofop application at 28 DAIT could not overcome the antagonism observed at earlier evaluations 14 and 28 DAIT. In addition, quizalofop activity on barnyardgrass was antagonized by saflufenacil at 14 DAIT. Bentazon mixed with quizalofop resulted in a neutral response for barnyardgrass control at all evaluation dates. As with red rice, CLXL-745, and CL-111 at all DAIT, barnyardgrass treated with quizalofop plus carfentrazone or thiobencarb resulted in a neutral response, indicating the potential for use as a mixture in an ACCase-R rice production system for control of these weeds.

3.3. Long-term study. The entire research area reverted to the producer's rotational crop in 2016. The entire area was planted to CLXL 745 rice and treated with clomazone 336 g ha^{-1} plus penoxulam at 40 g ai ha^{-1} plus halosulfuron at 53 g ai ha^{-1} oz/A applied preemergence. The grower sprayed applications of imazethapyr at 70 g ai ha^{-1} at the one- to two-leaf stage fb 70 g ai ha^{-1} at the four-leaf to one-tiller stage. Rotation 4, which included 3 years of consecutive soybean reduced weedy rice to 50 plants ha^{-1}, and Rotation 1 employed a soybean-rice-soybean-rice rotation with ACCase-R rice planted the 2nd year, 2014, which resulted in a final count to 60 plants ha^{-1} in 2016. These populations were compared with the grower program in an adjacent area with 100 times more weedy rice plants in 2016.

Conclusions

In conclusion, it is important that one understand the compatibility between quizalofop when applied in mixture with other herbicides. These data suggest that the application of quizalofop mixed with common herbicides used in rice production can result in an antagonistic response resulting in yield reduction, thus potentially reducing economic returns. However, the long-term research indicates ACCAse-resistant rice can be a useful in reducing weedy rice infestations.

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USE OF LOYANT® FOR SEDGES CONTROL IN FLOODED RICE CROPS

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ABSTRACT

Weed resistance to herbicides has increased and has become a key challenge for agriculture in the world. In Brazil, several weeds such as *Echinochloa crus-galli*, *Oryza sativa*, *Cyperus iria*, *Cyperus difformis*, *Sagittaria montevidensis* and *Fimbristyllis miliacea* have developed resistance to ALS-inhibitor herbicides in flooded rice, due to their intense use. In addition, *E. crus-galli* populations with multiple resistance to quinclorac ALS and ACCase herbicides have been identified. Loyant is a new Arylpicolinate herbicide with synthetic auxinic MOA developed by Corteva Agriscience for global use in rice. Loyant is formulated as NeoEC (25 g a.i./L) which dispenses adjuvants use. The objective of this study was to evaluate the efficacy of Loyant against key sedge species in flooded rice. Field trials were conducted in 2014-2015, 2015-2016 and 2016-2017 rice cropping seasons to evaluate Rinskor efficacy on *Cyperus iria*, *Cyperus esculentus* and *Cyperus difformis* in key Brazilian rice regions. Loyant was tested at 0.8, 1, 1.2, 1.4 and 1.6 L/ha rates, and Penoxsulam (0.2 L/ha) plus Vegetable Oil (1 L/ha) as commercial standard. Efficacy and rice crop response were evaluated, respectively at 45 and 15 days after application. Loyant demonstrated good efficacy on all evaluated sedges, even in fields with *Cyperus difformis* ALS-resistant biotypes. For *C. difformis* and *C. esculentus*, Loyant at 0.8 L/ha was enough to deliver more than 95% control at 45 days after application. For *C. iria*, Loyant at 1.2 L/ha was enough to deliver more than 95% of control. All Loyant evaluated rates were safe to rice.

Key words: Resistance management, alternative MOA, weed control.

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Use of Loyant® for Sedges Control in Brazilian Flooded Rice Crops.

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Introduction

Weed resistance to herbicides has increased and has become a key challenge for agriculture in the world. In Brazil, several weeds such as *Echinochloa crus-galli*, *Oryza sativa*, *Cyperus iria*, *Cyperus difformis*, *Sagittaria montevidensis* and *Fimbristyllis miliacea* have developed resistance to ALS-inhibitor herbicides in flooded rice, due to their intense use. In addition, *E. crus-galli* populations with multiple resistance to quinclorac ALS and ACCase herbicides have been identified. Loyant is a new Arylpicolinate herbicide with synthetic auxinic MOA developed by Corteva Agriscience for global use in rice. Loyant is formulated as NeoEC (25 g a.i./L) which dispenses adjuvants use.

Objective

Evaluate the efficacy of Loyant against key broadleaves in flooded rice.

Material and Methods

Field trials were conducted in 2014-2015, 2015-2016 and 2016-2017 rice cropping seasons to evaluate Loyant efficacy on *Cyperus iria*, *Cyperus esculentus* and *Cyperus difformis* in key Brazilian rice regions.

The location of trials, weed specie, weed stage, plant density, crop variety, crop stage and time to flood are described in Table 1.

Loyant was tested at 0.8, 1, 1.2, 1.4 and 1.6 L/ha rates, and Penoxsulam (0.2 L/ha) plus Vegetable Oil (1 L/ha) as commercial standard. Efficacy and rice crop response were evaluated, respectively at 45 and 15 days after application.

Table 1: Location of trials, weed specie, weed stage, plant density, crop variety, crop stage and time to flood.

Trial location	Weed	Density (m^2)	Weed stage (leaves)	Crop Variety	Crop stage	Time to flood (days)
Santa Maria	CYPIR	18	2-4	Puitá	3-4 fl	5
São Gabriel	CYPIR	10	2-5	Puitá	4 fl-1af	2
	CYPES	9	2-4			
Rosário do Sul	CYPES	8	2-5	Puitá	4 fl-1af	3
Itaqui	CYPIR	31	5	Puitá	4 fl-1af	2
Agudo	CYPES	23	3	IRGA428	4 fl-1af	5
Agudo	CYPDI	500	3	Epagri114	4-5 af	Inund.
Santa Maria	CYPIR	29	2-6	Guri	4 fl-1af	1
S. do Livramento	CYPES	30	4-6	Guri	3 fl	7
	CYPIR	800	4-5			
Dom Pedrito	CYPES	10	2-5	Puitá	4 lf-1af	4
Agudo	CYPDI	110	5-6	ANDOSAN	4 af	Inund.
Cachoeirinha	CYPES	63	4-6	Irga424	4 fl	1
Mogi Mirim	CYPIR	25	2	Irga424	2 fl	3
Mogi Mirim	CYPIR	52	6	Irga424	4-5 fl	5

Results

Table 2: Visual control of *Cyperus iria*, *Cyperus esculentus* and *Cyperus difformis* evaluated at 45 days after application and visual crop injury evaluated at 30 DAA.

Treatments ($L\ ha^{-1}$)	*C. iria* (45 DAA)[4] %	*C. esculentus* (45 DAA) %	*C. difformis* (45 DAA) %	Crop injury (30 DAA) %
Loyant 0,8	83 (60-100)[3] A[1]	92 (80-100) AB	100 (100-100) B	1 (0-10) BC
Loyant 1,0	89 (70-100) AB	97 (85-100) AB	100 (100-100) B	1 (0-15) BC
Loyant 1,2	96 (75-100) BC	99 (80-100) A	100 (100-100) B	3 (0-20) AB
Loyant 1,4	98 (85-100) BC	100 (100-100) A	100 (100-100) B	3 (0-20) AB
Loyant 1,6	99 (90-100) C	100 (100-100) A	100 (100-100) B	4 (0-30) A
Ricer 0,2	92 (70-100) BC	95 (80-100) B	74 (70-80) A	1(0-6) C
Untreated	-	-	-	0 C

[1]Mean followed by same letter do not differ significantly by the Tukey test 5%;
[2]Veget Oil at 1 L/ha;
[3]Mean of 40 experimental units (minimal and maximal assessment for each treatment);
[4]Days after application of treatments.

Conclusions

Loyant demonstrated good efficacy on all evaluated sedges, even in fields with *Cyperus difformis* ALS-resistant biotypes. For *C. difformis* and *C. esculentus*, Loyant at 0.8 L/ha was enough to deliver more than 92% control at 45 days after application. For *C. iria*, Loyant at 1.2 L/ha was enough to deliver more than 95% of control. All Loyant evaluated rates were safe to rice.

Picture 1: Plot showing Loyant (1.2 L/ha) control of *Cyperus iria*.

Consequences of early bloom of nuisance algae in rice: the case of California

Sara Ohadi

ABSTRACT

The main adapted method of planting rice in California is the aerially spread of pregerminated into the flooded field. This method of planting would provide a head start for rice seedlings against weeds. However, it could favor the rapid bloom of nuisance algae. Rapid, early formation of algal mats could prevent the establishment of newly emerged rice seedlings. Whether the occurrence of nuisance algae bloom would reduce rice seedling emergence and establishment has yet to be investigated. Here we designed a controlled outdoor experiment to test how the algae infestation level would impact the rice seedling emergence and establishment. The experiment we utilized in 15 gallon tubs filled with rice field soil. To simulate different algae infestation level (no algae, medium and high), various amount of fertilizers N: P including 0:0, 75:35 and 150:70 kg ha^{-1} were added to the soil surface prior to adding water. Sixty rice seeds (M206) were soaked for 24 hours and spread into tubs filled with water. Each algae infestation level had 10 replicates and the whole experiment were repeated three times. Water Temperature data was collected using Hobo data loggers. Emerged rice seedlings (i.e. when the rice is out of the water) were counted every second day for five weeks. A Sample of water (50ml) was also collected every week for chlorophyll *a* measurement. Photosynthetic active radiation (PAR) inside the water was measured every other day using a hand held PAR meter. A similar pattern of rice seedling emergence and establishment were observed across the three experiment runs. The results showed that the overall rice emergence declined by the increase of the chlorophyll *a* content, which is to say the higher the algae infestation. The Chlorophyll *a* content of above 500 ugml-1 could reduce rice seedling emergence by 90%. In addition, the rate of rice seedling emergence (time to 25% of emergence) was slower when there is high algae infestation. Our results shows that uncontrolled algae could reduce rice stand by up to 90%. Given that algae infestation has a patchy pattern in the field, loss of rice stand in these patches could provide empty niches for other weeds to grow. Further studies, yet to be done to estimate how much algae could reduce the rice yield.

Loyant herbicide, a new mode of action for the challenging weed management in rice in Chile.

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ABSTRACT

Since the commercial introduction of the active ingredients cyhalofop and penoxsulam in the last 20 years, an important selection pressure of ALS and ACCase herbicides has been detected over *Echinochloa spp*. in rice cultivation in Chile. The consequence of this management is the lack of activity of these key actives, that has consequently ended in reduction of crop yield.This situation is mainly explained due to the lack of good performing chemical alternatives. Loyant, is a new herbicide developed by Corteva Agriscience, containing the new active ingredient Rinskor that presents an auxinic mode of action. More than twenty-four trials had been carried out since 2013, assessing weed control performance and crop selectivity of Loyant alone and mixed with the most used commercial herbicides. Results show that Loyant alone at 30 g ai/ha is an effective tool controlling *Echinochloa sp., Cyperus difformis* and *Alisma lanceolata*, including those biotypes that ALS and ACCase herbicides where not able to control. For the control of *S. mucronatus*, triclopyr was found to be the best partner of Loyant. In terms of crop safety, Loyant showed comparable levels of selectivity than commercial standards at wide range of rates (15 – 60 g ai/ha).

Key words: Resistance management, *Echinochloa*, *Cyperus*

Loyant herbicide, a new tool for the challenging weed management in rice in Argentina.

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ABSTRACT

Since the commercial introduction of Bispyribac in 2000-01, and later with the introduction of the Clearfield technology in 2005-06, an important selection pressure against ALS herbicides has been made during more than 15 years in the rice fields of Argentina. Today, the consequence of this non-sustainable weed management practice is evident: herbicides that were extremely effective then, are no longer good performing products. *Echinochloa sp*. and *Cyperus sp*. are the weed species that are now challenging the rice production in Argentina. Loyant, is a new herbicide developed by Corteva Agriscience, containing the new active ingredient Rinskor that presents an auxinic mode of action. Forty-two trials had been made since 2013, assessing the weed control performance of Loyant and the most used commercial herbicides. Results shows that Loyant is an effective tool to control both *Echinochloa sp*. and *Cyperus sp*., including the biotypes that are not controlled by ALS-based products such as Bispyribac and Imidazolinones. In some trials, the tank mix of Loyant+Kifix (Imazapic+Imazapyr) was also tested as an alternative for field situations where there were simultaneous presence of ALS resistant *Echinochloa* and/or *Cyperus* with red rice. The result of this tank mix provided excellent control as well.

Key words: weed management, rice, Argentina, Rinskor, *Echinochloa*, *Cyperus*

Loyant herbicide, a new tool for the challenging weed management in rice in Argentina.

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Introduction

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Objective

Demonstrate the value of Loyant Herbicide, as a new tool that will help farmers to control ALS resistant ECHSS and CYPIR.

Material and Methods

Starting in 2013, several trials were made during the characterization of Loyant in Argentina. In all of these trials, a CO2 backpack sprayer with a 6 nozzle boom was used. Plot size were 3 meters wide and 6 meters long. Every two plots, a lateral untreated check was used for comparison purposes. Visual control in percentage (%) was the assessment used to compare the treatments. More than one rating was made in each of the trials, however with the objective of presenting summarized data, results and analysis will show assessments from 3 to 5 and 6 to 10 Weeks after application (WAA).

All trials were done in farmers field, meaning the products were tested under the exact same conditions the farmer would use the product. Several weeds were assessed, however in this study the focus will be in Echinochloa sp. (44 trials) and Cyperus sp. (18 trials). The graph below shows the quantity of trials and location for each weed, Echinochloa sp. (blue) and Cyperus sp. (Orange).

The treatments selected for the analisis were:

1. Loyant (Rinskor) – 1.2 lts/ha
2. Rebelex (Cyhalofop+Penoxsulam) – 1.6 lts/ha
3. Kifix (Imazapic + Imazapyr) – 180 grs /ha
4. Nominee (Byspiribac) – 100 gai/ha
5. Loyant+Kifix – 1,2+180 lts-grs/ha

Tuckey was used for mean differences. Significance level was 0.05.

Results

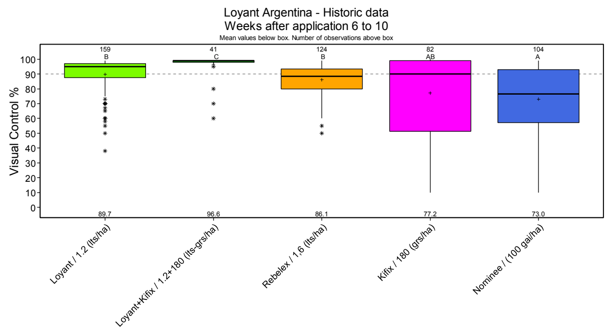

Figure 1. Visual control of Echinochloa sp. 6 to 10 weeks after application.

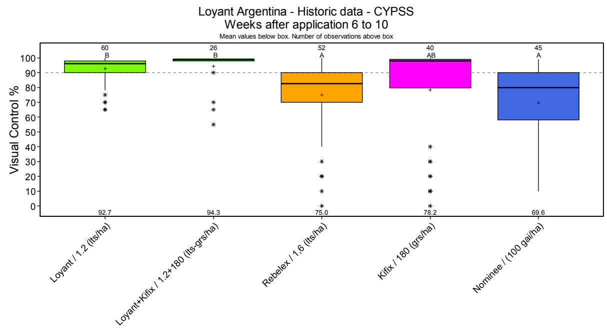

Figure 2. Visual control of Cyperus sp. 6 to 10 weeks after application.

Picture 3. Plot showing Loyant control of Echinochloa sp. and Cyperus sp. On the right and below the plot Untreated check.

Conclusions

Echinochloa sp. and Cyperus sp. clearly evolved and tools that were effective 10 years ago, are no longer as effective. In this context, Loyant shows to be an excellent tool to help farmers manage this challenging situation. The mix of Loyant + Kifix, means the possibility to continue using Clearfield systems to control red rice, keeping with Loyant a good control of Echinochloa and Cyperus.

Evaluation of Post-emergence Herbicide Activity on Louisiana Aquatic Weeds

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ABSTRACT

A field study was conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the activity of herbicides on troublesome aquatic weeds common to Louisiana rice fields rotated with crawfish aquaculture production systems. Plot size was 1.5 m by 5.2 m and a 91-cm diameter galvanized metal ring was installed within each plot for herbicide treatment containment and to provide a defined area for transplanting aquatic weeds. Grassy arrowhead (*Sagittaria graminea* Michx.), pickerelweed (*Pontedaria cordata* L.), and ladysthumb (*Polygonum persicaria* L.) were transplanted 3 weeks prior to treatment to allow for plant establishment. The area was also infested with a naturally occurring stand of ducksalad (*Heteranthera limosa* (Sw.) Willd.), yellow nutsedge (*Cyperus esculentus* L.), and alligatorweed (*Alternanthera philoxeroides* (Mart.) Grisb.). No rice was planted in this study to minimize competition between rice plants and weeds. Herbicide treatments consisted of seven herbicides labeled for use in rice production, applied alone or in mixture. All treatments included crop oil concentrate at 1% v v^{-1}. Application consisted of treating the entire plot area with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} spray solution and a handheld spray boom with five flat-fan 110015 nozzles at 38-cm spacing. Visual injury ratings were collected at 14, 28, 42, and 56 DAT. At the conclusion of the study, 56 DAT, plants were hand-harvested, grouped by species and fresh weight biomass was determined. A pre-packaged mixture of halosulfuron plus prosulfuron applied at 55, 83, or 111 g ai ha^{-1} controlled yellow nutsedge and pickerelweed 96% to 97% and no biomass was present in the containment ring at the conclusion of the trial. This pre-packaged applied at 83 and 111 g ai ha^{-1} controlled alligatorweed 96% and no biomass was present for this species, 56 DAT.

Key words: herbicide, rice, *Oryza sativa*, aquatic weeds.

Evaluation of Post-emergence Herbicide Activity on Louisiana Aquatic Weeds

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Introduction

South Louisiana rice fields are typically rotated with crawfish (Procambarus clarkii Girard) aquaculture production systems. In this rotational system, flood irrigation water often remains on the field for 11 to 12 months. Extended periods of inundation with flood water create an environment that is suitable for aquatic weeds. Many of these weed species have robust, perennial growth habits and can be difficult to control. Aquatic weed species that commonly infest this rotational system in Louisiana include grassy arrowhead (Sagittaria graminea Michx.), pickerelweed (Pontedaria cordata L.), ladysthumb (Polygonum persicaria L.), common cattail (Typha latifolia L.), and creeping burhead [Echinodorus cordifolius (L.) Griseb.]

Objective

The objective of this field trial was to evaluate seven different herbicide, alone or in mixture, for the post-emergence control of troublesome aquatic weeds that are common in Louisiana rice fields rotated with crawfish aquaculture production systems.

Material and Methods

A field trial was conducted in the 2019 growing season at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana. No rice was planted in this study to minimize competition between weeds and rice plants and to evaluate only the activity of the herbicides. Design was a randomized complete block design with four replications and plot size was 1.5 by 5.1 m. A 91-cm galvanized metal ring was placed within each plot for treatment containment and to establish a defined area for transplanting aquatic weeds. Grassy arrowhead, pickerelweed, and ladysthumb were transplanted into the rings 3 weeks prior to treatment, and the area was also naturally infested with alligatorweed [Alternanthera philoxeroides (Mart.) Grisb.], yellow nutsedge (Cyperus esculentus L.) and ducksalad [Heteranthera limosa (Sw.) Willd.] (Image 1). Seven different herbicides were applied , alone or in mixture, and 1% v v-1 crop oil concentrate was added to each herbicide treatment. Treatments were applied over the entire plot area with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Visual control was evaluated at 14, 28, 42, and 56 DAT and weeds were hand-harvested, grouped by species, and fresh weight biomass was determined at the conclusion of the study, 56 DAT

Results

At 56 DAT, grassy arrowhead, pickerelweed, yellow nutsedge, and alligatorweed were controlled 96%, 97%, 96%, and 96%, respectively, following treatment with the pre-packaged mixture of halosulfuron plus prosulfuron at 111 g ai ha^{-1} (Tables 1, 2, and 3)(Image 2). Florpyrauxifen-benzyl applied at 15 g ai ha^{-1} controlled ladysthumb, grassy arrowhead, pickerelweed, and alligatorweed 39%, 68%, 96%, and 92%, respectively, at 56 DAT (Image 3).Ladysthumb, grassy arrowhead, pickerelweed, and ducksalad were controlled 68%, 96%, 90%, and 80%, respectively, following treatment with florpyrauxifen-benzyl applied at 30 g ai ha^{-1}, 56 DAT (Image 4). At 56 DAT, ladysthumb, grassy arrowhead, pickerelweed, and alligatorweed were controlled 71%, 97%, 89%, and 86%, respectively, following treatment with penoxsulam applied at 40 g ai ha^{-1} (Image 5). An application of benzobicyclon at 246 g ai ha^{-1} tank-mixed with the pre-packaged mixture of halosulfuron plus prosulfuron at 111 g ai ha^{-1} controlled ladysthumb, pickerelweed, yellow nutsedge, and grassy arrowhead 69%, 92%, 98%, and 60%, respectively, at 56 DAT (Image6). No grassy arrowhead, pickerelweed, yellow nutsedge, and alligatorweed biomass was present in the containment ring following treatment with the pre-packaged mixture of halosulfuron plus prosulfuron at 111 g ai ha^{-1}, 56 DAT.

Image 1. Nontreated plot with galvanized metal ring.

Image 2. Aquatic weeds treated 83 g ai ha^{-1} of the prepackaged mixture of halosulfuron plus prosulfuron.

Image 3. Aquatic weeds treated with 15 g ai ha^{-1} of florpyrauxifen-benzyl.

Image 4. Aquatic weeds treated with 30 g ai ha^{-1} of florpyrauxifen-benzyl.

Image 5. Aquatic weeds treated with 40 g ai ha^{-1} of penoxsulam.

Image 6. Aquatic weeds treated with a tank-mixture of 246 and 55 g ai ha^{-1} of benzobicyclon and halosulfuron plus prosulfuron, respectively.

Table 1. Visual control of yellow nutsedge and ladysthumb 14, 28, 42, and 56 DAT and fresh weight biomass at the conclusion of the study, 56 DAT.

Herbicide Treatment	Rate	yellow nutsedge					ladysthumb				
	g ai ha^{-1}	% Control				biomass -grams-	% Control				biomass -grams-
		14DAT	28DAT	42DAT	56 DAT		14DAT	28DAT	42DAT	56 DAT	
nontreated	—	0 d	0 d	0 d	0 d	53 b	0 f	0 f	0 g	0 g	298 a
halosulfuron + prosulfuron	55	86 a	86 a	94 a	97 a	0 e	64 bcd	66 bc	78 bc	78 bc	55 de
halosulfuron + prosulfuron	83	84 ab	83 ab	94 a	97 a	0 e	74 ab	74 ab	83 b	88 a	19 e
halosulfuron + prosulfuron	111	85 a	85 a	92 ab	96 a	0 e	81 a	79 a	93 a	90 a	18 e
florpyrauxifen-benzyl	15	78 ab	76 a	94 a	97 a	0 e	53 d	49 d	61 ef	39 f	142 bcd
florpyrauxifen-benzyl	30	81 ab	83 a	93 ab	97 a	0 e	59 cd	54 d	69 de	55 e	68 de
penoxsulam	40	74 b	74 a	85 c	78 c	14 de	64 bcd	58 cd	68 def	71 cd	35 e
penoxsulam + triclopyr	336	84 ab	81 a	86 bc	84 b	8 e	74 ab	66 bc	70 cd	79 b	41 e
triclopyr	420	0 d	0 d	0 d	0 d	42 bc	29 e	0 f	0 g	0 g	221 ab
benzobicyclon	246	28 c	31 c	0 d	0 d	31 cd	5 f	26 e	0 g	0 g	99 cde
benzobicyclon + halosulfuron + prosulfuron	246 + 55	78 ab	83 a	94 a	98 a	0 e	56 cd	51 d	60 f	69 d	46 de
saflufenacil	25	36 c	33 c	0 d	0 d	90 a	68 bc	64 c	0 g	0 g	188 bc
saflufenacil	50	31 c	49 b	0 d	0 d	52 b	84 a	76 a	0 g	0 g	183 bc

Table 2. Visual control of grassy arrowhead and pickerelweed 14, 28, 42, and 56 DAT and fresh weight biomass at the conclusion of the study, 56 DAT.

Herbicide Treatment	Rate	grassy arrowhead					pickerelweed				
	g ai ha^{-1}	% Control				biomass -grams-	% Control				biomass -grams-
		14DAT	28DAT	42DAT	56 DAT		14DAT	28DAT	42DAT	56 DAT	
nontreated	—	0 f	0 d	0 c	0 e	377 a	0 g	0 g	0 b	0 c	332 b
halosulfuron + prosulfuron	55	84 a	93 a	95 a	93 b	16 d	68 cd	74 cd	95 a	97 a	0 d
halosulfuron + prosulfuron	83	89 a	91 a	95 a	96 ab	0 d	69 cd	88 ab	95 a	96 ab	0 d
halosulfuron + prosulfuron	111	91 a	94 a	97 a	96 ab	0 d	74 bc	88 ab	95 a	97 a	0 d
florpyrauxifen-benzyl	15	80 d	91 a	76 b	68 c	123 c	81 ab	91 a	96 a	96 ab	0 d
florpyrauxifen-benzyl	30	92 c	95 a	95 a	96 ab	0 d	88 a	90 ab	91 a	90 ab	25 d
penoxsulam	40	89 a	91 a	94 a	97 a	0 d	48 f	70 d	90 a	89 b	23 d
penoxsulam + triclopyr	336	91 a	93 a	95 a	97 a	o d	73 bcd	81 bc	90 a	91 ab	12 d
triclopyr	420	20 e	0 d	0 c	0 e	373 a	0 g	0 g	0 b	0 c	551 a
benzobicyclon	246	34 d	35 c	0 c	0 e	184 bc	0 g	0 g	0 b	0 c	648 a
benzobicyclon + halosulfuron + prosulfuron	246 + 55	66 b	75 b	90 a	60 d	248 b	51 f	59 e	90 a	92 a	5 d
saflufenacil	25	55 bc	34 c	0 c	0 e	134 c	56 ef	34 f	0 b	0 b	109 cd
saflufenacil	50	49 c	36 c	0 c	0 e	162 bc	64 de	36 f	0 b	0 b	176 c

Table 3. Visual control of ducksalad and alligatorweed 14, 28, 42, and 56 DAT and fresh weight biomass at the conclusion of the study, 56 DAT.

Herbicide Treatment	Rate	ducksalad					alligatorweed				
	g ai ha^{-1}	% Control				biomass -grams-	% Control				biomass -grams-
		14DAT	28DAT	42DAT	56 DAT		14DAT	28DAT	42DAT	56 DAT	
nontreated	—	0 e	0 f	0 e	0 d	2499 abc	0 g	0 f	0 d	0 e	53 b
halosulfuron + prosulfuron	55	91 bc	85 cd	73 d	28 c	2346 bc	80 a-d	89 ab	73 c	74 d	14 de
halosulfuron + prosulfuron	83	91 bc	86 cd	76 d	38 b	2110 c	74 cd	85 ab	91 a	96 a	0 e
halosulfuron + prosulfuron	111	89 c	84 d	73 d	35 b	1215 d	84 abc	86 ab	94 a	96 a	0 e
florpyrauxifen-benzyl	15	97 a	96 a	94 ab	76 a	110 e	88 ab	85 ab	86 ab	92 ab	9 de
florpyrauxifen-benzyl	30	97 a	97 a	97 a	80 a	95 e	92 a	91 a	91 a	81 cd	17 cde
penoxsulam	40	95 ab	94 ab	86 bc	36 b	810 de	68 d	70 cd	86 ab	93 ab	0 e
penoxsulam + triclopyr	336	95 ab	94 ab	89 abc	28 c	695 de	83 abc	66 d	76 bc	86 bc	8 de
triclopyr	420	0 e	0 f	0 e	0 d	2651 abc	79 bcd	39 e	0 d	0 e	35 bc
benzobicyclon	246	31 d	36 e	0 e	0 d	1259 d	34 f	38 e	0 d	0 e	24 cd
benzobicyclon + halosulfuron + prosulfuron	246 + 55	94 ab	90 bc	85 c	26 c	1120 d	71 cd	80 bc	74 c	0 e	0 e
saflufenacil	25	0 e	0 f	0 e	0 d	2870 ab	53 e	41 e	0 d	0 e	44 bc
saflufenacil	50	0 e	0 f	0 e	0 d	3252 a	44 ef	41 e	0 d	0 e	90 a

Conclusions

Results from this trial indicate that the adoption of new chemistries and pre-packaged mixtures, including florpyrauxifen-benzyl and halosulfuron plus prosulfuron, along with cultural practices will assist growers managing these weeds in South Louisiana rice/crawfish rotations.

Evaluation of New Rice Herbicides in a Salvage Situation in Louisiana Rice

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ABSTRACT

Early season weed management is typical in rice production; however, situations arise where early weed management fails prior to flooding. Postemergence weed management after the flood is established is often referred to as a salvage situation. Salvage treatments can be problematic due to the advanced growth stage of weeds and inadequate herbicide coverage.

Research was conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, LA to evaluate the potential of new rice herbicides applied in a salvage situation. Herbicides evaluated were: florpyrauxifen-benzyl at 14.5 and 29 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, halosulfuron plus prosulfuron at 55 and 83 g ai ha^{-1}, halosulfuron plus thifensulfuron at 53 g ai ha^{-1}, Orthosulfamuron at 94 g ai ha^{-1}, and orthosulfamuron plus quinclorac at 490 g ai ha^{-1}. Treatments were applied after flooding when rice was at the 2- to 3-tiller growth stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} with five flat-fan 110015 nozzles spaced 35 cm apart.

At 28 DAT, each rate of florpyrauxifen-benzyl, the 83 g ha^{-1} rate of halosulfuron plus prosulfuron, and orthosulfamuron plus quinclorac controlled alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.] 89 to 98%. Control for alligatorweed was reduced when treated with all other herbicides and rates evaluated. At 42 DAT, All halosulfuron-containing products and the 29 g ha^{-1} rate of florpyrauxifen-benzyl controlled yellow nutsedge (*Cyperus esculentus* L.) 92 to 99%. Control was reduced when yellow nutsedge was treated with all other products and rates. Rice treated with halosulfuron plus prosulfuron at 83 g ha^{-1} resulted in a rough rice yield of 5110 kg ha^{-1}. Yield was reduced to 4106 kg ha^{-1} when treated with the 53 g ha^{-1} rate of florpyrauxifen-benzyl.

Key words: salvage, alligatorweed, *Alternanthera* philoxeroides, yellow nutsedge, *Cyperus esculentus*, florpyrauxifen-benzyl, halosulfuron, halosulfuron plus prosulfuron

Evaluation of New Rice Herbicides in a Salvage Situation in Louisiana Rice

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Introduction

Rice weed management programs are typically designed to control weeds early in the growing season; however, situations often arise where this approach cannot be sustained until the rice is flooded. Postemergence weed management after the flood is established is often referred to as a salvage situation (Bond and Walker 2012). Salvage treatments can be problematic due to the advanced growth stage of weeds and poor spray coverage from the developing rice/weed canopy. Typical salvage applications in Louisiana include ALS-inhibiting herbicides such as halosulfuron for broadleaf and sedge management and fenoxaprop or cyhalofop for grass management. ALS-inhibiting herbicide resistant sedges have been reported in the midsouthern United States (Heap 2020).

In 2018, two new herbicides were released for use in rice production in the Midsouthern United States: florpyrauxifen-benzyl and a prepackaged mixture of halosulfuron and prosulfuron. Florpyrauxifen-benzyl, an auxin mimicing herbicide, is sold under the trade name Loyant by Corteva Agriscience and has activity on broadleaf, sedge, and grass weeds. The prepackaged mixture of halosulfuron and prosulfuron, two ALS-inhibiting herbicides, is sold under the trade name Gambit by Gowan Company and has activity on broadleaf and sedge weeds.

Objective

The objective of this study is to compare the broadleaf and sedge activity of florpyrauxifen-benzyl and halosulfuron plus prosulfuron to other herbicides used in a salvage situation in Louisiana drill-seeded rice production.

Material and Methods

- Conducted in 2017 and 2018 at the H. Rouse Caffey Rice Research Station South Unit near Crowley, Louisiana
- Cultivar: PVL01 drill-seeded at 67 kg ha^{-1}
- Plot size: 1.5 x 5.2 m
- Treatments replicated four times in a randomized complete block
- Herbicide application:
    - Applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}
    - Timing: 2-3 tiller PLV01 rice
    - Nozzle: FF110015 spaced 35 cm apart
- Treatments:
    - Clomazone applied PRE at 336 g ai ha^{-1} to all treatments for grass management
    - Florpyrauxifen-benzyl (Loyant) at 14.5 and 29 g ai ha^{-1}
    - Halosulfuron (Permit) at 53 g ai ha^{-1}
    - Halosulfuron plus thifensulfuron (Permit Plus) at 53 g ai ha^{-1}
    - Halosulfuron plus prosulfuron (Gambit) at 55 and 83 g ai ha^{-1}
    - Orthosulfamuron (Strada) at 94 g ai ha^{-1}
    - Orthosulfamuron plus quinclorac (Strada XT2) at 490 g ai ha^{-1}
- Evaluations and analysis:
    - % rice injury (data not shown) and weed control at 14, 28, and 42 DAT
    - PVL01 rice height at harvest (data not shown)
    - Rough rice yield
    - Mean separation using Fisher's LSD with $P \leq 0.05$

Results

- *Cyperus esculentus* control for the highest rate of florpyrauxifen-benzyl and each rate of halosulfuron plus prosulfuron was 92 – 99% at 42 DAT, similar to the other halosulfuron containing treatments (Table 1).
- *Alternanthera philoxeroides* control was 92 – 99% at each evaluation date when treated with either rate florpyrauxifen-benzyl or the high rate of halosulfuron plus prosulfuron, compared with halosulfuron at 21 and 24% control, respectively, for each evaluation date.
- All products controlled *Sesbania herbacea* greater than 97% at each evaluation date.
- When treated with florpyrauxifen-benzyl, *Caperonia palustris* control was similar to the nontreated at each evaluation date, compared with orthosulfamuron control at 64 and 74% at 28 and 42 DAT, respectively.
- PVL01 rice yields were 4560 kg ha^{-1} when treated with the high rate of halosulfuron plus prosulfuron. A similar response was observed for PVL01 rice treated with orthosulfamuron containing products.

Photo 1. Representative of nontreated rice plots

Photo 2. Representative of rice treated with the high rate of halosulfuron plus prosulfuron

Conclusions

Halosulfuron and orthosulfamuron containing products are typically used for broadleaf and sedge weed management in salvage situations across Louisiana; however, both florpyrauxifen-benzyl and halosulfuron plus prosulfuron exhibited similar or greater activity for the weeds evaluated in this study except *Caperonia palustris*. Utilizing a higher rate of halosulfuron plus prosulfuron improved PVL01 rough rice yield by 1280 kg ha^{-1} compared with the lower rate, due to increased activity on *Alternanthera philoxeroides* and *Caperonia palustris*. Yield reductions for PVL01 rice treated with florpyrauxifen-benzyl can likely be attributed to inactivity on *Caperonia palustris* and slower activity on *Cyperus esculentus*. In Conclusion, these two new products have great potential for use in salvage situations in Louisiana rice production where *Cyperus esculentus*, *Sesbania herbacea*, or *Alternanthera philoxeroides* are present.

References

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Heap (2020) International survey of herbicide resistant weeds. doi: http://www.weedscience.org/

Table 1. *Cyperus esculentus* (CYPES), *Sesbania herbacea* (SEBEX), *Caperonia palustris* (CNPPA), and *Alternanthera philoxeroides* (ALRPH) control with each herbicide and PVL01 rough rice yield for each treatment. Numbers with different letters in columns are significantly different using Fisher's LSD ($P \leq 0.05$).

	CYPES		SEBEX		CNPPA		ALRPH		PVL01 Yield
Treatment	28 DAT	42 DAT	28 DAT	42 DAT	28 DAT	42 DAT	28 DAT	42 DAT	KG HA^{-1}
Nontreated	0 d	0 f	0 c	0 c	0 f	0 f	0 f	0 h	2045 e
Loyant (14.5 g ha^{-1})	76 b	83 b	99 a	99 a	6 ef	6 ef	94 ab	93 ab	3340 cd
Loyant (29 g ha^{-1})	78 b	92 a	99 a	99 a	9 ef	13 e	98 a	99 a	3670 bc
Gambit (55 g ha^{-1})	89 a	98 a	97 ab	98 a	49 c	21 d	85 b	85 cd	3280 cd
Gambit (83) g ha^{-1})	90 a	99 a	99 a	99 a	55 bc	33 c	92 ab	93 ab	4560 a
Permit	83 ab	99 a	98 a	99 a	14 e	8 ef	21 e	24 g	2810 de
Permit Plus	86 a	99 a	99 a	99 a	31 d	9 e	50 d	58 f	3590 bcd
Strada	68 c	44 d	99 a	97 ab	64 ab	74 a	73 c	70 e	4270 ab
Strada XT2	61 c	68 c	99 a	98 a	59 ab	65 b	89 ab	89 bc	4030 abc
LSD ($P \leq 0.05$)	7.8	7.8	2.5	2.6	8.8	8.7	12.3	7.4	839.7

Seed shattering in weedy rice is not similarly regulated as in cultivated rice

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ABSTRACT

Although seed shattering is one of the main causes of weedy rice persistence it still is poorly understood. The aim of this study was to identify the main genes related with the occurrence of seed shattering in weedy rice. Gene expression and DNA sequencing of the coding and promoter region and a whole genome sequencing were performed in weedy and cultivated rice with contrasting seed shattering. The main genes associated with the seed shattering in cultivated rice *Sh4, qSH1* and *SHAT1* were not important in weedy rice. The expression of the gene *OsCPL1* was positively associated with high seed shattering in weedy rice, which is the opposite than in cultivated rice. This result is related to the absence of four SNPs and an indel in the OsCPL1 gene in weedy rice. The analysis of the expression of six genes related to cell wall synthesis/degradation pioneering revealed the importance of the genes *OsXTH8* and *OsCel9D* to seed shattering in weedy rice. The nucleotide variability of eight genes identified on a genome-wide re-sequencing study in cultivated rice indicated that only the genes *Os01g0849100* and *Os08g0512400* were associated with seed shattering in weedy rice. The whole genome sequencing of genotypes with high seed shattering indicates a variation on the promoter region of the gene *OsXTH8*. An insertion of G or C on this region next to the gibberellin motif was identified in all weedy rice genotypes with high seed shattering. This study evaluated jointly a series of genes involved in rice seed shattering and indicated that genes *qSH1, Sh4* and *SHAT1* are not important in weedy rice, and that the genes *OsCPL1, OsCel9D, OsXTH8, Os08g0512400* and *Os01g0849100* should be considered in studies of weedy rice evolution and in the development of mitigation approaches gene flow between cultivated and weedy rice.

Key words: Abscission layer, *Oryza sativa, qSH1*, red rice, seed dispersal, *Sh4.*

Tolerance to flooding during germination and early growth of weedy rice

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ABSTRACT

Flooding is an important method for weedy rice control. The reduction of the flooding effect on germination and initial growth of weedy rice has been observed, which compromise the efficiency of flooded rice systems. The objectives of this study were to establish a methodology for the selection of weed rice populations with flooding tolerance, to evaluate the expression of genes associated to flooding in cultivated rice, and to investigate the effect of temperature and soil depth on tolerance to flooding in weedy rice. A total of 160 genotypes of cultivated and weedy rice were evaluated in three flooding depths (saturated soil, 5.0 and 10.0 cm). The germination of the flooding tolerant weedy rice genotype ITJ03 was higher than 90% at 25 and 30 °C, but was totally suppressed at temperature of 20 °C and 10 cm of flooding depths. The emergence was also suppressed at burial depths over 2 cm and under 10 cm flooding depths, indicating the cumulative effect of these two factors. There is large variability of weedy rice genotypes to tolerate the flooding effect at germination and initial growth. Relative expression of *RAmy3D* and *OsTPP7* genes increased in 30.58 and 46.71 times, respectively, at the four days after sowing (DAS) for the weedy rice tolerant genotype. The ITJ03 genotype at one day after sowing had the expression of *ADH2* and *SNRK1* genes induced by flooding about 63 times. The temperature of 20 °C reduced the expression of all the evaluated genes in the shoots and roots. The tolerance to flooding during germination and initial growth in weedy rice is associated with the expression of RAmy3D, *OsTPP7, ADH2* and *SNRK1* genes. Low temperatures together with flooding depths decrease the emergence of weedy rice.

Key words: Anoxia, flooding tolerance, germination, hypoxia, *Oryza sativa*.

Differences in seed longevity between quinclorac-resistant and susceptible barnyardgras

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ABSTRACT

The objective of this research is to quantify the longevity of seeds of biotypes resistant and susceptible to the herbicide quinclorac, verifying if there are differences between them, when seeds are on the soil surface or buried at 15 cm of depth. The experiment was installed on April 2013. Enough seeds of quinclorac resistant- and susceptible-biotypes were placed in PVC pipes buried at 15 cm depth and at the surface for a sampling period of five years. Extractions were made every three months, corresponding to each season of the year during the first three years, and every six months extractions in the last two years. The viability and dormancy of the seeds were studied through germination and tetrazolium tests, respectively. The experimental design consisted on a completely randomized block design with sub-sub-divided plots, and six replicates. The plots corresponded to the year of extraction (2013 to 2018), the sub-plot the soil depth (0 and 15 cm), and the sub-sub-plot the biotype (susceptible and resistant to quinclorac).Regardless biotypes, seed viability was reduced in the successive extractions, being the reduction greater for the seeds deposited on the surface than those buried. Resistance to the herbicide quinclorac did not affect the viability of the seed or modify the seasonal dormancy cycles of *Echinochloa crus-galli* at any depth studied. After 5 years of seeds burying at 15 cm depth, they continue having high potential for re-infestation, when they come back to the soil surficial horizons by means of soil tillage.

Key words: *Echinochloa crus-galli*, viability, dormancy, seed bank

1. Introduction

Approximately 40% of the rice acreage in Uruguay is sown each year on rice stubble, and the rest of the area in rotation with pastures or idle land for two or more years. In these systems, herbicides have been an effective tool in integrated weed management. However, the continued use of the same active ingredients determined selection pressure in the populations towards individuals that tolerate herbicides. Herbicide resistance is a result of the selection for traits that allow weed species to survive specific management practices which would otherwise cause mortality (Powles, 1994). Quinclorac is a highly selective herbicide that has had an important use in most regions where rice is grown. Resistance in weeds to this herbicide has been reported in various rice producing regions. In the eastern part of Uruguay, Saldain and Sosa (2015) reported resistance of barnyardgrass biotype to quinclorac, showing a new aspect to be considered in the integrated management of weeds in rice cultivation in Uruguay.

Weeds when evolved herbicide resistance sometimes lose or diminish some of their survival abilities (Gressel, 2009). Since the longevity of the seeds is a characteristic of great importance in the survival capacity of weed species, this could be affected by the acquisition of herbicide resistance. Some authors mention that the longevity of the seeds depends critically on the dormancy mechanisms that prevent completely embedded seeds from germinating (Cook, 1980), however, Baskin and Baskin (2001) stated that the only type of dormancy that can be a great cause for the persistence of the seeds is physical dormancy (hard seeds). On the other hand, knowing the dynamics of the viability and dormancy of the seeds of these species becomes relevant in the management of rice cultivation. The objective of this work is to quantify the longevity of seeds of biotypes resistant and susceptible to the herbicide quinclorac, verifying if there are differences between them, when placed on the soil surface and buried at 15 cm depth.

2. Material and Methods

A field experiment was carried out in the Experimental Unit Paso de la Laguna of the Instituto Nacional de Investigación Agropecuaria in Treinta y Tres state, Uruguay. It was installed on April 28, 2013. The seeds of *Echinochloa crus-galli* were collected in the eastern region of Uruguay, being biotypes quinclorac-susceptible and another quinclorac-resistant. Both biotypes presented zero percent of germinated seeds at the time of the trial installation, and a viability of 96.5% for the resistant and 96.8% for the susceptible biotypes, respectively. These seeds were deposited on the soil surface or buried at 15 cm, for a period of five years. Extractions were made every three months corresponding to each season of the year during the first three years, and every six months in the last two years. The viability was calculated as the product of the percentage of seeds recovered and their respective percentage of viability. In each repetition, 100 seeds placed in PVC open tubes of 10 cm diameter, buried at 15 cm soil depth were used, and the tubes corresponding to the surface seed were buried halfway, distributing the seed in the area of the tube. Ninety-six cylinders were buried per treatment. The unearthed tubes were taken to the laboratory where the seeds were recovered. Initially live and dead seedlings were counted and then the earth was crumbled looking for the seeds visually. Seeds that were not visually damaged were placed to germinate on paper with alternating temperatures of 20-30° C. Seeds germinated on the fourteenth day and the number of seedlings born in the field constituted the portion of viable quiescent (non-dormant) seeds. The experimental design consisted on a completely randomized block design with sub-sub-divided plots, and six replicates. The plots corresponded to the year of extraction (2013 to 2018), the sub-plot the soil depth (0 and 15 cm), and the sub-sub-plot the biotype (susceptible and resistant to quinclorac). The statistical analysis of variables was done using proc Mixed (SAS Institute, v9.4) and the comparison of means using the Tukey test ($P < 0.05$).

3. Results and Discussion

The viability of the seeds is presented in Figure 1, In this, the changes that occurred in the successive extractions for the two biotypes and depths under study can be observed.

In fall 2013, when the trial was installed, the seeds had 97% viability (100% corrected). The viability of the seeds was reduced in the successive extractions, being significantly lower for the seeds deposited on the surface ($P < 0.05$). The difference in longevity of the seeds at different depths has already been verified by many authors for several species, where the seeds buried deeper have greater longevity (Miller and Nalewa, 1990; Noldin et al 2006).

Viable surface seeds showed an abrupt drop in the first year, obtaining average values of around 20%. These seeds did not remain viable by the third summer, finding viability percentages less than 10% in this last year. On the contrary, seeds buried at 15 cm maintained a high percentage of viable seeds until the third year, 56% on average for both biotypes. At the fall of the fifth year, 21% of viable seeds remained in the soil on average. Seeds can remain 100% viable for 6-8 years in dry condition (Maun and Barrett 1986); longevity in soil varies according to soil texture. Echinochloa species, specifically barnyardgrass, were reported to remain viable up to 13 years in sandy loam soil when buried at 20 cm depth with 3% of viability (Dawson and Bruns 1962).

Soil and climate, according to Bekker et al (1998) can influence these longevity differences, however, this influence is not decisive, since persistence is above all a characteristic of the seed, which may or may not be modified by environmental conditions (Fenner and Thompson, 2005). Interaction between depth at different moments of extraction was found for viability. The number of seeds of the total deposited decreased over time, especially on the surface. These losses are given, among other factors, by the germination of the seeds on the surface, the action of the microfauna, and greater exposure to climatic factors.

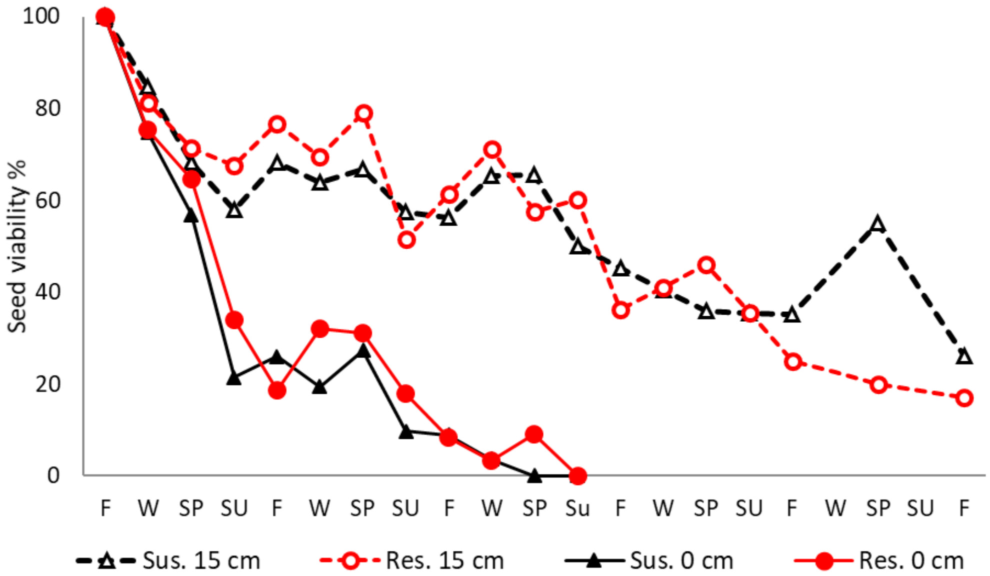

Figure 1. Evolution of the seed viability (%) of resistant (Res) and Susceptible (Sus.) biotypes. Seeds of *Echinocloa crus-galli* buried at 15 cm and on the surface (0 cm) were seasonally extracted (F = fall; W= winter; SP = spring; SU = summer); experiment began in the fall of 2013. P <0.05%.

In the viable seeds obtained in each season of the year there were changes in the proportions of dormant and quiescent. Figure 2 shows the evolution by season of dormancy and quiescence of seeds of the two biotypes and at both depths. At the end of April 2013, less than two months after harvest, seeds were 97% dormant and 0% quiescent.

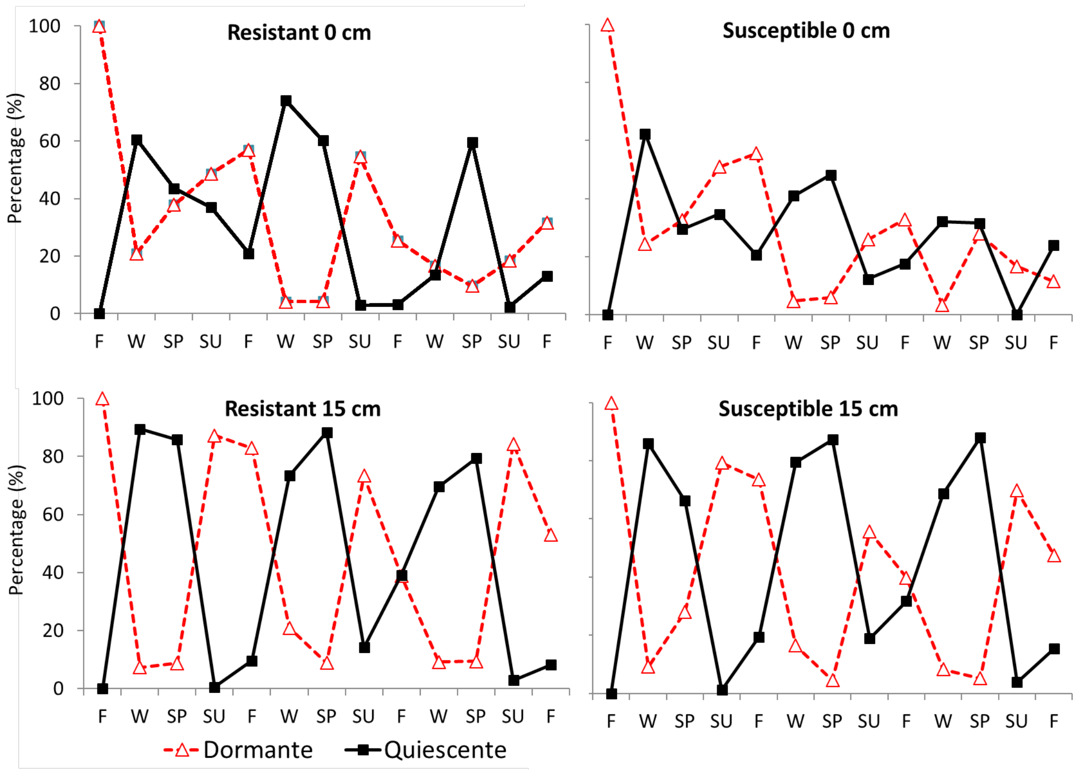

Figure 2. Evolution percentage of dormant and quiescent seeds of resistant and susceptible biotypes *Echinocloa crus-galli* on surface (0 cm) and buried at 15 cm in seasonal extractions from fall 2013 to 2018 (F=fall; W=winter; SP=spring; SU=summer).

Three months later, in the winter, dormancy was overcome and most of the seeds passed to a quiescence condition. This difference is greater in the seeds buried at 15 cm, presenting an average of almost 90% quiescence, the seed being more affected by the variations in soil and climate conditions. In spring, this situation began to be reverted slowly, increasing the number of dormant seeds and decreasing the quiescent ones until reaching a maximum of dormancy in the summer. This cyclical behavior was repeated the other years for both depths and biotypes.

Between the biotypes, no differences were found in the proportions of dormant and quiescent seeds, with a similar behavior at both depths. Between the depths, however, there are differences in both the percentage of dormant and quiescent seeds. There were differences in the percentage of dormant and viable seeds in the average of the different moments of extraction.

Conclusions

Seeds buried deeper had greater viability than those on surface, for biotypes resistant and susceptible to quinclorac. Resistance to the herbicide quinclorac did not reduce the viability of the seed or modify the seasonal dormancy cycles of *E. crus-galli* at both depths evaluated. After five years buried at 15 cm, seeds continue with a high potential for re-infest rice fields if they are taken to the surface.

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Effect of Nitrogen Fertilization, Seed Treatment, and Simulation of Root Damage by Insects on the Severity of Rice Blast (*Pyricularia oryzae* cav.) in the Panicle

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ABSTRACT

Rice is one of the most important cereal crops cultivated in Brazil, especially in the Rio Grande do Sul State. The application of increased doses of chemical fertilizer and the use of susceptible cultivars are the main causes of the increasing severity of rice blast (*Pyricularia oryzae* Cav.) in the field. This is also one of the causes of the increasing damage from other diseases and pests reflecting in increasing yield losses as well.

This study was conducted to investigate the effects of dose and timing of nitrogen application, and doses of insecticide/fungicide, Standak Top, in seed treatments. We also simulated the damage in the roots caused by the insect pest *Oryzophagus oryzae* to access its effect on the development of rice blast (*Pyricularia oryzae* Cav.). The experiment was conducted under field conditions in a randomized complete block design with ten treatments and four replications, and the data were analyzed as a split-plot design (with or without cutting the roots to simulate the damage by *Oryzophagus oryzae*).

The results indicated that: 1) The Control treatment provided low severity of panicle blast, regardless of the damage simulated by insects through cuts in the roots; 2) The application of 100% of the recommended dose of N in the vegetative growth stage V3 (which corresponds to the flooding timing) caused the highest blast severity in the panicle, regardless of the seed treatment doses and the damage simulation by insect through cuts in the roots; 3) The simulation of insect damage through cuts in the roots caused an increase in the blast severity in the panicles when the recommended dose of N was divided into 50% in the vegetative phase V3 and 50% in the reproductive growth stage R0 and together with the seed treatment at doses of 100 mL and 150 mL of fungicide / insecticide.

Key words: paddy rice, disease, control, management.

Lignin content in rice roots sclerenchyma affects the South American rice water weevil (Col.: Curculionidae) growth and fitness

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ABSTRACT

Host-plant resistance is an essential tactic that could be incorporated into the IPM program for rice water weevil *Oryzophagus oryzae* (Coleoptera: Curculionidae), an important pest to flooded rice in South America. In this study, we investigated some root anatomical traits in rice cultivars that could be associated with antibiosis effects on *O. oryzae*. Under field conditions, a biennial experiment was conducted using a Latin square design, with four cultivars in plots with 100 plants, and 15-cm flooding depth. Antibiosis resistance among cultivars was evaluated by comparing the density and weight of larvae, the time required to emergence 50% of offspring adults (ET_{50}) and the weight of offspring adults emerged. For the study of root anatomy among cultivars, at 25 days after flooding root samples from the first 9-cm of the root system of rice plants were collected in the field and processed in the lab. A manual rotary-microtome was used for obtaining transversal cuts 7 µm in width. Larval density and weight were respectively ~3.5 and 1.7-fold higher in 'BRS Pampa CL' and 'BRS Querência' than in 'BRS Firmeza' and 'Dawn'. Consequently, 'BRS Pampa CL' and 'BRS Querência' presented the shortest ET_{50} of adults as well the highest adults body weight. There were visible anatomical differences among resistant and susceptible cultivars. The roots from the resistant cultivars BRS Firmeza and Dawn exhibited sclerenchyma arranged in three cell layers with high lignin content. Additionally, a slightly smaller cortex formed by parenchyma cells arranged in more compact layers (few intercellular spaces) were observed. These root structural traits seem to be related to the antibiotic effects of rice cultivars BRS Firmeza and Dawn on *O. oryzae*, since lignin plays an important role in increasing the vegetal toughness that reduces the feeding by herbivores, and also decreases the nutritional content of vegetal.

Keywords: antibiosis, antifeedant effects, *Oryzophagus oryzae*, host-plant resistance.

Lignin content in rice roots sclerenchyma affects the South American Rice Water Weevil (Col.: Curculionidae) growth and fitness

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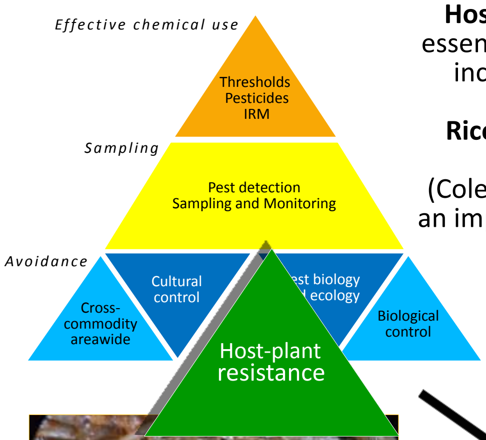
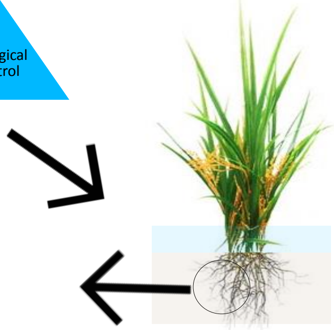
Introduction



Host-plant resistance is an essential tactic that could be incorporated into the IPM program for **Rice Water Weevil (RWW)** *Oryzophagus oryzae* (Coleoptera: Curculionidae), an important pest to flooded rice in South America.



Rice Water Weevil
Oryzophagus oryzae (Col.: Curculionidae)

Objective

The goal of this study was investigated some root anatomical traits in rice cultivars that could be associated with **antibiosis** effects on *O. oryzae*.

Material and Methods

Study area:
Embrapa, Capão do Leão, RS, Brazil;
Crop season:
2016/17; 2017/18;
Treatment= rice cultivars
BRS Firmeza (Firm);
BRS Pampa CL (Pamp);
BRS Querência (Quer);
Dawn (Dawn);
Experimental desing:
Latin square;

Assessements:
Antibiosis test
- Larvae= Number; Weight (mg). Sampling = 15, 25 and 35 Days After Flooding (DAF);
- Offspring adult= Time required to emergence 50%; Weight (mg);

Root anatomy on plants collected at 25 DAF;
Statistical analysis:
ANOVA; Scott Knott (P<0.05)

Results

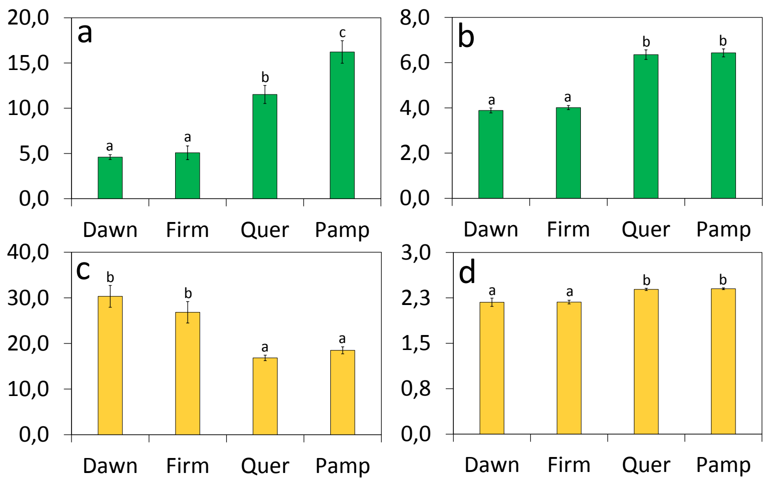


Fig.1 Number (a) and weight (b) of larvae (mean value from samplings at 15, 25 and 35 DAF), time required to emergence 50% (c) and weight (d) of offspring adult of the RWW.
Mean values followed by the same letter does not differ significantly by the Scott Knott test (P<0.05)

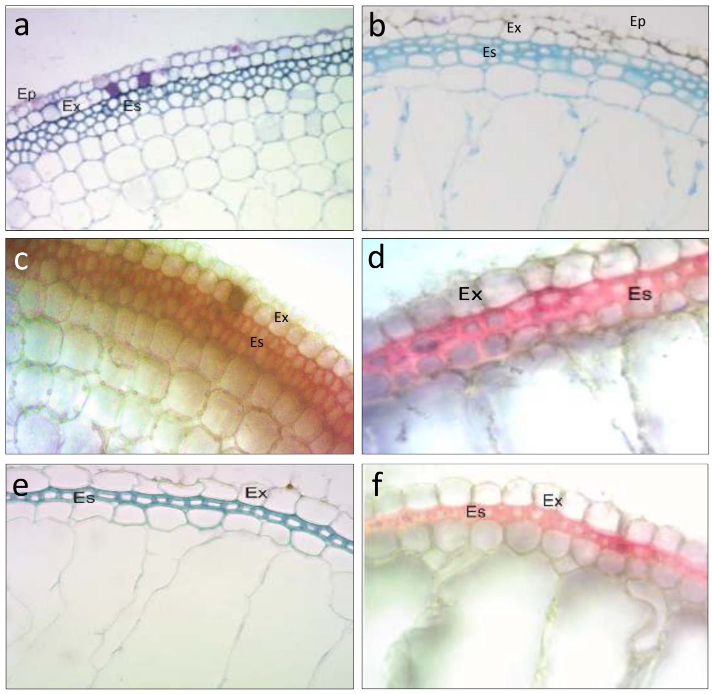


Fig.2 Root anatomy of resistant ["Dawn"= (a), (c), "Firm"= (b), (d)] and susceptible ["Pamp"= (e), (f)] rice cultivars to the RWW (samples collected at 25 DAF); Lignin detection in sclerenchyma cells (red color) [(c), (d), (f)]. Ep= epidermis; Ex= exodermis; Es= sclerenchyma.

Conclusions

1 BRS Firmeza and Dawn have antibiosis-type resistance to the rice water weevil;

2 Sclerenchyma arranged in three cell layers with high lignin content seem to be related to the antibiotic effects of BRS Firmeza and Dawn on *O. oryzae*.

Does rice seeding date influences pre-emergence herbicides efficiency for barnyardgrass control?

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ABSTRACT

Pre-emergence herbicides are an important tool for barnyardgrass (*Echinochloa* sp.) management on irrigated rice in South American paddies. The objective of this study was to measure the flow of emergence of barnyardgrass in three rice-seeding times and evaluate the residual of control provided by pre-emergence herbicides at these dates. The experiment was conducted in the Lowlands Experimental Station of Embrapa Clima Temperado, in Capão do Leão, RS, Brazil (-31.81S; -52.47W) in growing season 2019/2020. The three seeding dates were September 26, October 11 and November 11, after conventional soil tillage, using 80 kg/ha seeds of rice cultivar BRS Pampa CL. The experiment was arranged in randomized blocks with four replicates, with Individual plots of 10m². The herbicides were applied immediately after rice seeding, and consisted of penoxsulam 72g./ha, clomazone 288g/ha, pendimethalin 1200g/ha, quinclorac 375g./ha, imazapyr + imazapic (73.5+24.5) g./ha, oxyfluorfen 240g/ha, imazethapyr 150g/ha and a no-control check. On the same day as pre-emergence spraying, glyphosate (1440 g a.i/ha) was sprayed to control the weeds already emerged. Barnyardgrass seedlings were counted at 4, 11, 18 and 25 days after spraying, in a 0.5 x 0.25 m area inside the plots. In the same days, the emerged seedlings were hand plucked. Visual control and phytotoxicity were evaluated at 7, 14 and 21 days after spraying. Cumulative emergence data was analyzed and fitted to a quadratic linear equation; barnyardgrass control (%) and rice phytotoxicity (%) were analyzed trough F-test and means of treatments compared using Tukey test at P=0.05. Barnyardgrass infestation in the no-control checks was higher on October and November if compared to September. Quinclorac, pendimethalin and clomazone provided the longest residual control for September and October seeding dates, while for November oxyfluorfen presented a short residual period. Herbicide phytotoxicity on rice was noticed only for clomazone and oxyfluorfen, sprayed in the last seeding date. Results of visual control corroborate with the emergence flow of barnyardgrass: as higher is the weed density, lesser is weed control provided by the herbicides.

Key words: *Echinochloa*, emergence flow, residual, control.

Does the rice sowing date influences pre-emergence herbicides used for barnyardgrass control?

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Introduction

- Barnyardgrass is one of the most troublesome weed for rice production in Southern Brazil, especially because of its competitive ability and similarity with the crop.
- Moreover, in the last decade, ALS-resistant barnyardgrass biotypes were wide spread through producing areas and in high infestation levels.
- Pre-emergence herbicides are a very important tool for resistant-barnyardgrass management.

Objective

- The objective of this work was to measure barnyardgrass emergence flow in different rice sowing dates and the residual control provided by different pre-emergence herbicides.

Material and Methods

- The experiment was conducted at the Embrapa Clima Temperado experimental station in Capão do Leão-RS, in the 2019/2020 growing season, after tillage, using 80kg/ha of BRS Pampa CL seeds.

- **The three sowing times were**:
  - September 26th,
  - October 11st and
  - November 11th,

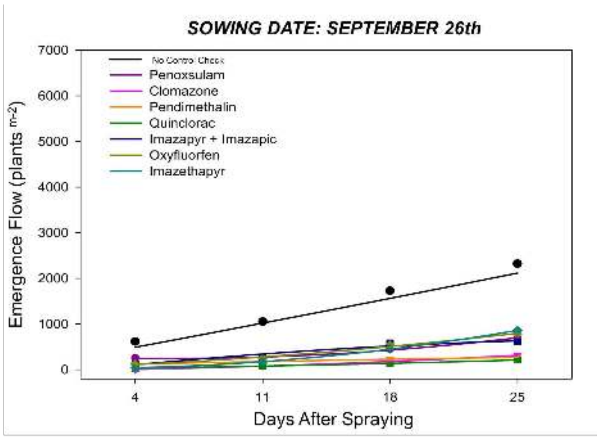
- Plots consisted of 10m², in a randomized blocks design.

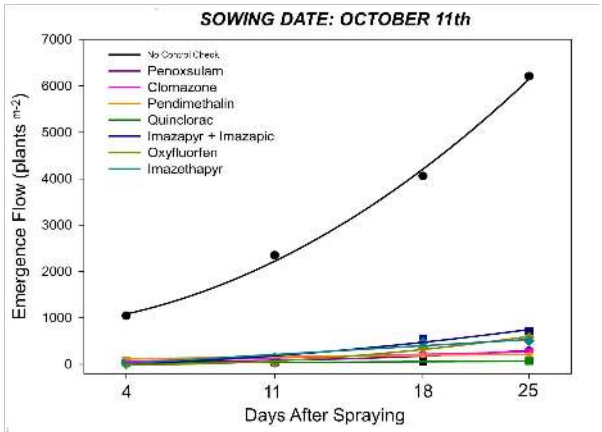
- **The pre-emergence herbicide treatments tested were:**
  - penoxsulam 72$g_{a.i.}$/ha,
  - clomazone 288$g_{a.i.}$/ha,
  - pendimethalin 1200$g_{a.i.}$/ha,
  - quinclorac 375$g_{a.i.}$/ha,
  - [imazapyr+imazapic] (73,5+24,5)$g_{a.i.}$/ha,
  - oxyfluorfen 240$g_{a.i.}$/ha and
  - imazethapyr 150$g_{a.i.}$/ha

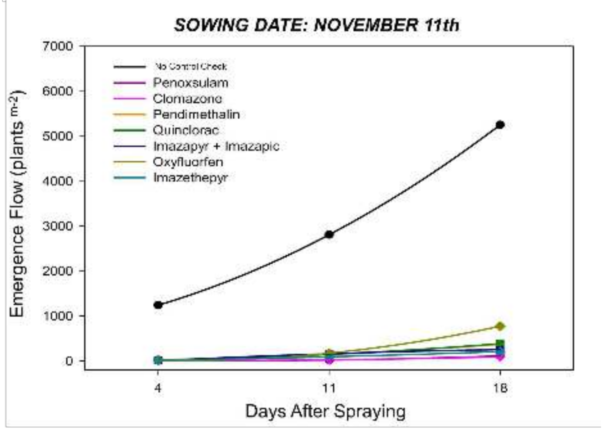
- On the same day as pre-emergence spraying, glyphosate (1440$g_{a.e.}$/ha) was sprayed in order to control barnyardgrass seedlings already emerged.
- Barnyardgrass seedlings were counted at 4, 11, 18 and 25 days after spraying, on a 0,25x0,25cm area inside the plots and hand plucked.

- Cumulative emergence data was analyzed using a quadratic linear equation.

Results







Conclusions

- Barnyardgrass infestation in the no-control checks was higher on October and November, and quinclorac, pendimethalin and clomazone provided the longest residual control for September and October, while for November oxyfluorfen had a really short residual period, differing from the other treatments.

Control of Jointvetch (*Aeschynomene* spp.), Establishment and Productivity of Rice as a Function of [Imazapic + Imazapyr] Doses

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Abstract - We aimed with this work to evaluate the efficiency of the herbicide [imazapic + imazapyr] in the weed control, especially of the jointvetch, and its reflex in plant establishment and rice grain yield. For this, a field study was conducted, where treatments were: control without herbicide application; Kifix® 140g ha^{-1} (24.5 g ha^{-1} imazapic + 73.5 g ha^{-1} imazapyr) and Kifix® 280 g ha^{-1} (49 g ha^{-1} imazapic + 147 g ha^{-1} imazapyr). We evaluated crop emergence up to 25 days after sowing; crop plant height 12 days after emergence (DAE); jointvetch plant density 31 and 62 DAE; jointvetch dry mass 62 DAE; as well as general weed infestation 62 DAE. At the end of the crop cycle we also evaluated grains per panicle; panicle and 1000 grain weight; panicle density; and crop grain yield. There is a risk of 5 - 10% reduction in the establishment of Clearfield® rice plants when the maximum dose of registration of the herbicide [imazapic + imazapyr] is applied pre-emergence, but under appropriate conditions, the crop development tends to compensate for this reduction in establishment. The herbicide [imazapic + imazapyr] is effective on jointvetch, but under high infestation conditions, more developed plants, problems in water management or intermittent irrigation, a complementary herbicide may be required to control Jointvetch, aiming to guarantee the grain yield levels of the crop.

Keywords: Kifix®; *Oryza sativa*; emergence; infestation; *Aeschynomene*.

Introduction

Rice is one of the most important cereals produced in the world. It is cultivated mainly in paddy fields using a continuous flood. In Brazil, Rio Grande do Sul (RS) and Santa Catarina (SC) States are the main producers, being responsible for approximately 80% of the national production, where the average productivity is 6,837 and 7,139 kg ha^{-1}, respectively (Conab, 2017).

Paddy rice cropping fields in southern Brazil are generally highly productive, although yield averages are still lower than those achieved in areas that adopt high-tech practices such as experimental fields. One of the main reasons for yield reduction in this crop is related to unsatisfactory weed control (Galon et al., 2007; Agostinetto et al., 2008). Their importance has been increasing due to the adoption of minimum till and the low efficacy of non-selective herbicides against them.

Among the main weeds in paddy rice in RS, weedy rice and *Echinochloa* sp are the most important, limiting crop productivity due to its competitive ability and is present in all regions of the state (Agostinetto et al., 2001). Currently, with the introduction of Clearfield® technology, the main control method used the application of herbicides belonging to the chemical group of imidazolinones. These herbicides inhibit the Acetolactate Synthase enzyme (ALS) and are highly efficient, practical and of fast action. However, the application of these herbicides at doses not recommended, with prolonged residuals and/or the absence of mechanisms of action rotation over time in the same area caused selection pressure (Vargas, 2017) and favored the appearance of resistant biotypes to imidazolinones. Thus, several biotypes of rice-weeds have already been found to be resistant to ALS-inhibiting herbicides in Brazil (Heap, 2017).

Another weed commonly found in rice fields is the jointvetch (*Aeschynomene rudis* and *A. denticulata*), which affects rice cultivation during the productive cycle, in harvesting and may also affect seed/grain quality. In addition, jointvetch produces large amounts of seeds, which contributes to the increase of the soil weed seed bank, interfering in subsequent crop cycles as well as in crops planted in succession to rice. It is a dicotyledonous that often requires herbicide applications specially directed to its control (Ferreira, 2007).

In rice fields planted with Clearfield® rice varieties, there are frequent complaints that the herbicide [imazapic + imazapyr], associated to the technology, may not exert high efficiency in the control of this weed. This situation is aggravated when the herbicide is applied to rice post-emergence, at a time when most jointvetch plants are taller, which leads some growers to use the maximum herbicide registration dose of [imazapic + imazapyr], with no clear information about the impact of this decision on Clearfield® rice establishment, or on the emergence of non-Clearfield® cultivars planted in succession.

Thus, we aimed with this work to evaluate the efficiency of the herbicide [imazapic + imazapyr] in the weed control, especially of jointvetch, and its effects on plant establishment and rice grain yield.

Material and methods

The study was installed in the experimental field owned by Embrapa Clima Temperado, Terras Baixas Station, Capão do Leão (RS), Brazil, geographic coordinates -31.8153; -52.4698 in randomized blocks design, with plots measuring 4 x 18 m (72 m^2), and four replications.

The vegetation burndown prior to planting was done with 1440 $g_{a.e.}$ ha^{-1} of glyphosate, seven days before sowing the cultivar Guri INTA CL, on November 9, 2016, in rows spaced in 0.17 m. The base fertilization consisted of 300 kg ha^{-1} of the formula N-P-K 5-25-25 applied to the planting row.

Treatments were: (T1) control without herbicide application; (T2) Kifix® 140 g ha^{-1} (24.5 g ha^{-1} imazapic + 73.5 g ha^{-1} imazapyr) and (T3) Kifix® 280 g ha^{-1} (49 g ha^{-1} imazapic + 147 g ha^{-1} imazapyr). The application was carried out one day after planting (DAP), via precision equipment propelled by CO_2, connected to a bar with six 110.02 nozzles spaced in 0.5 m, subjected to the necessary pressure to apply the equivalent to 150 L ha^{-1} of herbicide solution.

The emerged rice seedlings were counted every other day to obtain the emergence curve of the crop up to 25 days after planting, in two samples per plot, each sample consisting of two planting rows with 60 cm. Rice plant height was assessed 12 days after emergence.

Topdressing fertilization was done on two moments: beginning of tillering (09/12/2016) and a few days before panicle initiation (01/13/2017), each with 100 kg ha^{-1} of urea (45% N). Irrigation was established on December 9, 2016, 21 days after rice emergence. On 12/15/2016 (36 DAP), 375 g ha^{-1} of quinclorac were applied in all the area, including the control plots without Kifix®.

The density of jointvetch plants was assessed on December 19, 2016, shortly after the application of quinclorac (but with all plants still alive), and again 35 days after quinclorac application, on January 19, 2017. Jointvetch plants present in 4 m^2 samples per plot, were cut to soil level and dried into oven with forced air circulation 65 ± 5 ºC, until constant weight. Also during this period, the general infestation of the area by weeds (composed mostly by jointvetch, with a few individuals of barnyardgrass and other aquatics) was assessed.

Rice grain yield was assessed at the end of the cycle, when two samples of 4 m^2 per plot were harvested by hand and threshed, subjected to oven drying with forced air circulation at 65 ± 5 °C, after which the grains were weighed and their mass corrected to 13% humidity. The weight of one thousand grains and the weight of grains per panicle were evaluated by collecting five panicles per plot. We also counted the panicle density and the number of grains per panicle. At harvest, the weed infestation was assessed again.

We processed the experimental data through descriptive statistics with 95% confidence intervals, according to Cumming et al. (2004). By this method, the comparison between treatments is done based on an expected response interval for similar cropping situations, instead of only on the response of the treatments in the experiment. All analyzes were performed into the statistical environment "R".

Results and discussion

The emergence curve evidenced the onset of emergence around five days after planting (DAP), with stabilization of the number of plants in approximately 200 plants m^{-2}, at 18 DAP (Figure 1). There was also effect of the herbicide on rice plant establishment, and at 20 DAP, about 200 plants m^{-2} plants were observed in the control plot, while about 170 plants m^{-2} were observed under application of 280 g ha^{-1} (Figure 1), which represents a potential reduction of approximately 10% in the establishment of Guri Inta CL plants when the maximum registered dose of Kifix® is applied pre-emergence to rice.

It should be noted, however, that although this difference is noticeable, under application of 140 g ha^{-1}, in commercial fields, probably little or no damage would occur to the establishment of the crop plants, since rice is a very plastic plant and stand differences into this magnitude would be easily compensated by tillering (Sousa et al., 1995).

Rice plant height (Figure 2), on the other side, was stable among treatments, even at the highest dose. Twelve days after emergence (DAE), plants were between 11 and 14 cm tall in the control treatment; between 9 and 13 cm when using the dose of 140 g ha^{-1}, and between 10 and 14 cm for 280 g ha^{-1}.

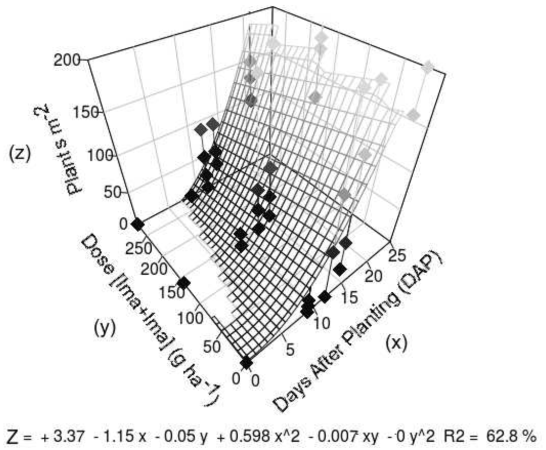

Figure 1. Emergence curve of rice plants cv. Guri IntaCL as a function of days after planting and Kifix® (imazapic+imazapyr) doses.

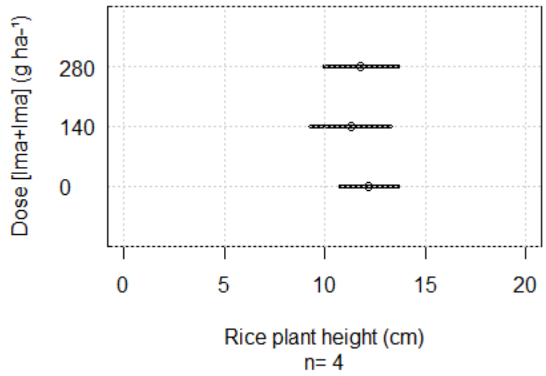

Figure 2. Rice plant height (cm) 12 days after emergence, as a function of Kifix® (imazapic+imazapyr) doses. Confidence intervals at 95% are presented.

Some studies have shown that although imidazolinone herbicides are highly selective to cultivars with the Clearfield® technology, other rice cultivars planted in the next cropping seasons may be injured by the residues of this herbicide in soil. For the non-tolerant cultivar IRGA 417, the residual effect of [imazethapyr + imazapic] resulted in reduction of plant stand, tiller and panicle density, plant height, sterility and dry mass (Kraemer et al., 2009). Supposing adverse conditions occur during the crop development, phytotoxicity can lead to reductions in rice grain yield since the crop may not have enough time to recover from the damage caused by the herbicides (Villa et al., 2006).

In another study, Sousa (2010) and Galon et al. (2012) reported increased toxicity to the tolerant cultivar Puitá INTA CL with increasing doses of Only® and Kifix®. However, throughout the crop cycle, the variety was able to recover from injuries, with no effect on grain yield. When evaluating the susceptibility of rice, bean and sorghum to Kifix®, Xavier et al. (2013) reported high sensitivity of rice cv. BRS Serra Dourada, with no crop emergence at residual doses above 0.9 mg of Kifix® dm^{-3} soil.

The herbicide [imazapic + imazapyr], although effective on jointvetch (Figure 3), was not sufficient to control this weed adequately under conditions of high infestation (abundant soil seed bank). At 31 DAE, between 22 and 38 jointvetch plants were observed in the control plot; between 9 and 28 plants under the usual dose (140 g ha^{-1}); and between 4 and 18 plants with the highest dose (280 g ha^{-1}) of [imazapic + imazapyr] (Figure 3). Therefore, even with the application of the maximum dose, the control of jointvetch does not seem to be sufficient in high infestation conditions, demanding the application of additional herbicides for the control this weed species.

With the complementary quinclorac application, the infestation dropped from 22 - 38 to 4 - 18 jointvetch plants m^{-2} in the control treatment, and from 4 - 18 to 0 - 6 plants m^{-2} where the highest dose of [imazapic + imazapyr] was applied (Figure 3). This illustrates that the control of jointvetch when using 375 g ha^{-1} of quinclorac, approaches to that obtained with the use of 280 g ha^{-1} of Kifix® pre-emergence. According, the jointvetch plants showed also lower dry mass accumulation for about 50% of the cases (Figure 4) for the treatment with the maximum dose of [imazapic + imazapyr] and complementary application of quinclorac, where every plant weighted 1 - 4 g. The usual treatment (140 g ha^{-1}) presented plants with between 2 and 5 g, being similar to the control plot. The less remarkable difference in jointvetch dry mass, compared to plant density, shows that [imazapic + imazapyr] is efficient pre-emergence of this species, but after emergence, the surviving plants mostly tend not to be inhibited by this herbicide.

Therefore, under high infestation conditions, control of jointvetch plants provided by [imazapic + imazapyr], although significant, should be complemented with the application of some other effective herbicide in the control of this species, including quinclorac (Fleck et al., 2008).

The overall level of weed infestation (Figure 5) was similar to that observed for jointvetch (Figure 3), as it was the predominant weed in the experiment. The general infestation was between 63 - 82% of the area in the control; 22 - 60% of the area with 140 g ha^{-1} of [imazapic + imazapyr], and 6 - 23% with 280 g ha^{-1} of the herbicide (Figure 5). These data suggest that under conditions of low natural infestation, only the application of [imazapic + imazapyr] may be sufficient to adequately inhibit the occurrence of weeds in rice fields with Clearfield® technology. Over time, however, the seed bank of jointvetch in these areas would most likely tend to increase, demanding additional herbicide applications.

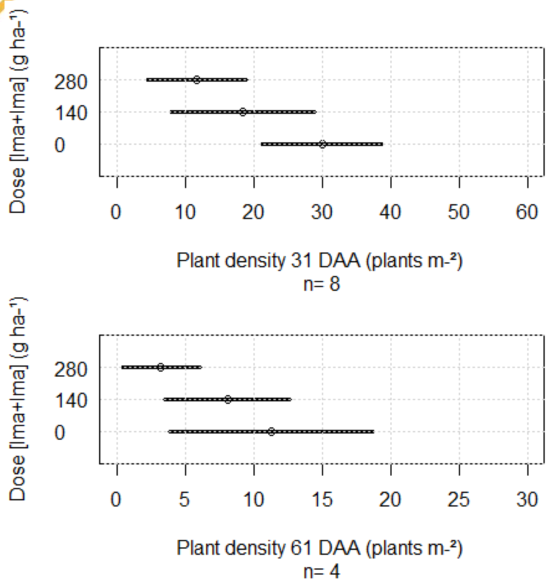

Figure 3. Jointvetch (*Aeschynomene* spp.) plant density (plantsm^{-2}) as function of the application of Kifix® (imazapic+imazapyr), complemented or not by quinclorac. Confidence intervals at 95% are presented.

Above: Plant density 31 days after application of Kifix pre-emergence, as function of the treatments;

Below: Plant density 62 days after application of Kifix (as function of treatments), and 30 days after the complementary application of quinclorac.

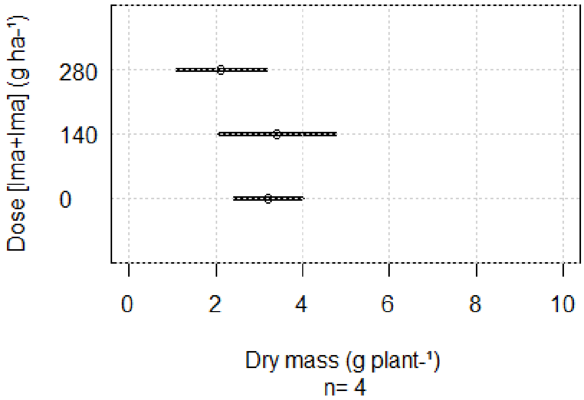

Figure 4. Jointvetch dry mass (g plant^{-1}) 62 days after crop emergence, as a function of Kifix® (imazapic+imazapyr) doses. Confidence intervals at 95% are presented.

This was confirmed when 107 DAE a re-infestation of weeds was observed, reaching 92 - 98% in the treatment without application of [imazapic + imazapyr]; 52 - 100% when using the recommended dose (140 g ha^{-1}); 14 - 65% when using 280 g ha^{-1}. Time periods with water levels below the ideal during this period, may have favored the emergence of new weeds since the germination of jointvetch - as for most weeds, is reduced by the water layer (Moraes, 2007); For this species, in particular, germination under a water layer may occur as long as the seeds are on the soil surface (Ferreira, 2007).

The imidazolinone herbicides, in general terms, have a long residual effect in soil. Marchesan et al. (2007) reported phytotoxicity and grain yield reduction in non-tolerant rice cultivars grown after two consecutive cultivations with application of [imazethapyr + imazapic]. Monquero et al. (2013) found diclosulam and imazaquim residues 90 days after application, regardless of the soil moisture, while Sousa (2010) detected these herbicides up to 1100 days after application with use of indicator plants. However, the behavior of the imidazolinone herbicides in the environment is variable; the persistence increases with the increase of clay and organic matter content of the soil, and reduces with the elevation of pH (Mangels, 1991; Oliveira Jr. et al., 1999; Stougaard et al., 1990; Schreiber et al., 2017). In this sense, the lower content of clay and organic matter in the planosols, can reduce the persistence of the herbicide, especially in aerated soil conditions as in the off-season/ winter.

Panicle grain weight was between 2.4 - 2.8 g panicle^{-1} for the control treatment; 2.5 - 3.1 g panicle^{-1} at the usual dose (140 g ha^{-1}); and 2.5 - 3 g panicle^{-1} at a 280 g ha^{-1}, with no substantial difference between treatments (Figure 6).

Therefore, the importance of the jointvetch (*Aeschynomene* spp.) as a competitor in irrigated rice is highlighted, and other studies should be developed with a focus on managing this weed, such as chemical alternatives to avoid that the Clearfield® system is threatened by the difficulty in controlling jointvetch under high infestation and/or deep and continuous water layer. In addition, rice cultivation systems with intermittent irrigation (Toescher et al., 1997; Watanabe et al., 2007; Mezzomo, 2009), which are becoming common in rice plantations in Rio Grande do Sul, can be a case where the Clearfield® technology may not be fully efficient in the control of jointvetch; therefore, in these conditions, an additional herbicide can be required.

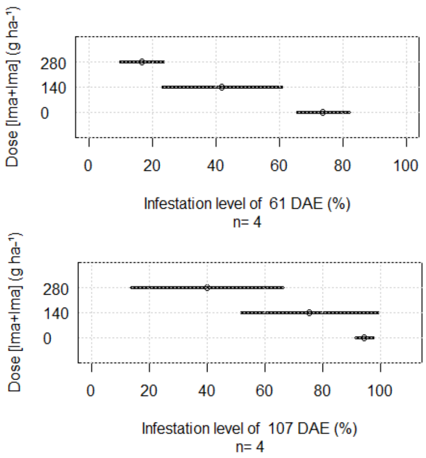

Figure 5. Infestation level of treatments by weed species 61 and 107 days after crop emergence, as a function of Kifix® (imazapic+imazapyr) doses. Confidence intervals at 95% are presented.

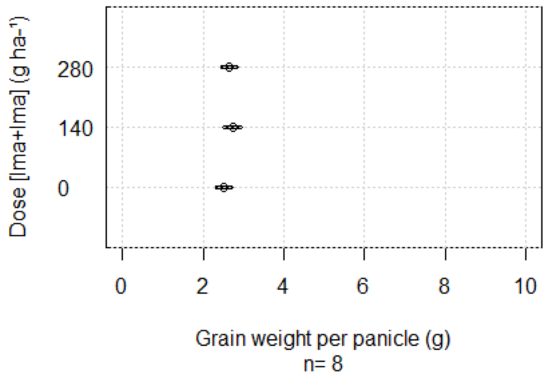

Figure 6. Grain weight per panicle (g) of rice plants at harvest, as a function of Kifix® (imazapic+imazapyr) doses. Confidence intervals at 95% are presented.

Conclusion

There is a risk of 5 - 10% reduction in the establishment of Clearfield® rice plants when the maximum dose of registration of the herbicide [imazapic + imazapyr] is applied pre-emergence, but under appropriate conditions, the crop development tends to compensate for this reduction in establishment. The herbicide [imazapic + imazapyr] is effective on jointvetch, but under high infestation conditions, more developed plants, problems in water management or intermittent irrigation, a complementary herbicide may be required to control jointvetch, aiming to guarantee the grain yield levels of the crop.

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Control of Jointvetch (*Aeschynomene* spp.), Establishment and Productivity of Rice as a Function of [Imazapic + Imazapyr] Doses

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Introduction

Paddy rice cropping fields in southern Brazil are generally highly productive. Meanwhile weeds can cause up to 90% of final crop damage. Among the main rice weeds, jointvetch (*Aeschynomene rudis* and *A. denticulata*) is one of the most important.

Aeschynomene spp.

Highly competitive

Large amounts of seeds

Crop interference

With the introduction of Clearfield® technology, the main control method used is with herbicides belonging to the chemical group of imidazolinonas.

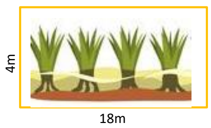
Clearfield® rice varieties → [Imazapic + Imazapyr] in post-emergency application → Difficult in controll the specie → Maximum herbicide registration dose → Impact on rice establishment?

Objective

Evaluate the efficiency of the herbicide [imazapic + imazapyr] in the weed control, especially of the jointvetch, and its reflex in plant establishment and rice grain yield.

Material and Methods

- The study was installed in the experimental field owned by Embrapa Clima Temperado, Terras Baixas Station, Capão do Leão (RS), Brazil.



- Plots: 72m² and four replications.
- Cultivar Guri INTA CL, on November 9, 2016, in rows spaced in 0.17 m.

Treatments

T1 control without herbicide application;
T2 Kifix® 140 g ha^{-1} (24.5 g ha^{-1} imazapic + 73.5 g ha^{-1} imazapyr);
T3 Kifix® 280 g ha^{-1} (49 g ha^{-1} imazapic + 147 g ha^{-1} imazapyr).

- On 36 DAP, 375 g ha^{-1} of quinclorac were applied in all the area, including the control plots without Kifix®.
- Were analyzed emergence of rice plants, plant density of jointvetch after application of Kifix® and grain weight per panicle.
- All analyzes were performed into the statistical environment "R". The experimental data through descriptive statistics with 95% confidence intervals, according to Cumming et al. (2004).

Results

The emergence curve evidenced the onset of emergence around five days after planting (DAP), with stabilization of the number of plants in approximately 200 plants m-2, at 18 DAP (Figure 1).

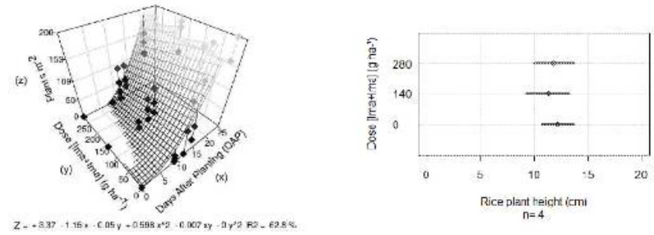


Figure 1: A) Emergence curve of rice plants cv. Guri Inta CL as a function of days after planting and Kifix® (imazapic+imazapyr) doses. B) Rice plant height (cm) 12 days after emergence, as a function of Kifix® (imazapic+imazapyr) doses.

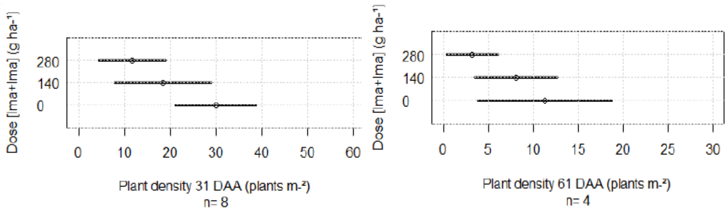


Figure 2: Jointvetch (*Aeschynomene* spp.) plant density (plants m^{-2}) as function of the application of Kifix® (imazapic+imazapyr), complemented or not by quinclorac.

Panicle grain weight was between 2.4 - 2.8 g $panicle^{-1}$ for the control treatment; 2.5 - 3.1 g $panicle^{-1}$ at the usual dose (140 g ha^{-1}); and 2.5 - 3 g $panicle^{-1}$ at a 280 g ha^{-1}, with no substantial difference between treatments.

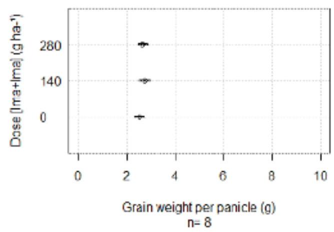


Figure 3: Grain weight per panicle (g) of rice plants at harvest, as a function of Kifix® (imazapic+imazapyr) doses.

Conclusions

There is a risk of a 10% reduction in the establishment of Clearfield® rice plants when the maximum dose of registration of the herbicide imazapic + imazapyr] is applied pre-emergence, but under appropriate conditions, the crop development tends to compensate for this reduction in establishment.

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Characterization of the Weedy Flora in Rice Areas under Distinct Cropping Systems and Herbicide Managements

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Abstract - We aimed with this study, to evaluate the incidence of weeds in flooded rice areas, in the pre-planting of the summer crop, as a function of the planting system and the use of herbicides in the previous cropping year. The experiment was installed in field conditions, in randomized complete blocks design, and 3 x 2 factorial scheme with eight replications. Treatments consisted on conventional tillage, minimum tillage and no-till cropping systems (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B). One year after rice cultivation, preceding the planting of the next cropping season, phytosociological evaluations of the weed communities present in the treatments were carried out. We assessed the overall infestation level and weed species composition. We also estimated the diversity coefficients of Simpson and Shannon-Weiner, as well as the sustainability coefficient SEP. Rice cultivation systems (traditional or semi-ecological), differ in the context where they should be inserted. Herbicide-based crops select companion weed species. Although in these systems, crop rotation and winter cover crops are preponderant, they are not a *sine-qua-non* condition for success. Semi-ecological systems require a different approach. Crop rotation, thick winter soil mulching and association with animal presence and grazing are essential for the short, medium and long-term inhibition of weeds. In these areas, hoeing – either man-powered or mechanized – is essential to ensure the success of rice cropping.

Keywords: chemical control; semi-ecological rice; phytosociology; southern Brazil.

Introduction

For crops to produce efficiently in a cropping system, some management practices are necessary to provide a favorable environment; but usually, these same practices favor the establishment of weeds more adapted to the given management system. In addition to management practices such as the cropping system, soil and climate traits influence the weed population (Godoy et al., 1995).

The use of herbicides for weed control is widely adopted, mainly in wide cropping areas or where the mechanical weed control method is not effective or viable (Siqueri, 2001). However, other weed flows could occur during the crop cycle, and a single herbicide application may be not enough for an efficient weed control (Ikeda et al., 2008). According to Dal Magro et al. (2006), plants may vary in their behavior following a herbicide application. In addition, herbicide abuse or mismanagement would ultimately result in the appearance of weed biotypes resistant to herbicides (Vargas et al., 2009).

The lack of knowledge on existing weed species in a particular crop and the inadequate use of control methods, often result in the excessive use of herbicides, increasing the risk of environmental contamination. In this sense, the identification of the weed species and the frequency in which they occur into cropping systems, is essential to subsidize the selection of the most appropriate herbicide (Pitelli, 2000; Silva et al., 2015).

In the no-till cropping system, weed seeds are located most closer to the soil surface; this information may be used as tool for weed management, since these weeds may be stimulated to germinate and later eliminated by chemical means, reducing significantly the infestation potential from the soil seed bank since the soil is not revolved (Monquero and Christoffoleti, 2005). Furthermore, the use of cover crops and the maintenance of mulching on the soil surface during the fallow would reduce light capture by weed seeds and seedlings, thus reducing the overall infestation (Teodoro et al., 2011).

According to Kuva et al. (2007), changes resulting from innovative agricultural production system impact the size of the weed population, since they act as a non-periodic ecological factor. Usually, the most adapted weed species to that level of environmental disturbance will prevail, which reflects on the soil seed bank (Soares et al., 2011) and on the long-term weed infestation.

Soil management systems impose particular microenvironments to the seeds, due to changes in their physical-chemical properties (Mulugueta and Stoltenberg, 1997); thus, the real demand for chemical control of weeds should rely on a previous survey and understanding of the weed species which occur on the distinct rice cropping systems (Voll et al., 2003), which can be estimated by the emergence rates of the species present in the soil seed bank. For this, the phytosociological survey has been used as tool for the characterization of the infestation pattern in agricultural areas, allowing to describe the structure of the weed community in a given field (Silva et al. 2015).

Therefore, we aimed with this study, to evaluate the incidence of weeds in flooded rice areas, in the pre-planting of the summer crop, as a function of the planting system and the use of herbicides in the previous cropping year.

Material and methods

The experiment was installed in field conditions, at Embrapa Clima Temperado, Pelotas-RS, Brazil, in randomized complete blocks design, and 3 x 2 factorial scheme with plots measuring 4 m x 4 m, with eight replications. Treatments consisted on conventional tillage, minimum tillage and no-till cropping systems (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B). Seeding was carried out with nine rows spaced in 0.175 m, on 09 Nov. 2016 with 100 kg ha^{-1} of the variety Guri Inta CL. The basic fertilization applied at the planting furrow consisted of 300 kg ha^{-1} of N-P-K 5-25-25.

For the planting system (Factor A), in the conventional system (Factor A, level 1), the area underwent plowing and disking prior to planting. In the minimum cultivation (Factor A, level 2), the area underwent two light diskings, 20 days before planting rice. For no-till (Factor A, level 3), the vegetation mulching was burndown 20 days prior to planting rice.

As for the chemical treatments, those without herbicide (Factor B, level 1) did not receive any application, not even for burndown prior to planting; the natural area mulching was only accommodated closer to soil by the planting operations. In plots where herbicides were to be applied (Factor B, level 2), the area was burndown 20 days before planting, with 1440 g ha^{-1} of glyphosate. Subsequently, 73.5 g ha^{-1} of imazapyr + 24.5 g ha^{-1} of imazapic (140 $g_{c.p.}$ ha^{-1} of Kifix) + 400 g ha^{-1} of clomazone were applied right after rice planting. Thirty-five days after emergence, the application of 375 g ha^{-1} of quinclorac was necessary for control of jointvetch (*Aeschynomene* spp.).

Flood irrigation was established on 08 Dec. 2016, 20 days after crop emergence, at the beginning of tillering (~ V3), by establishing a water layer of 7 cm, which was maintained throughout the cropping cycle. After harvesting, in April 2017, ryegrass (*Lolium multiflorum*) was established as winter cover at rate of 25 kg ha^{-1} of seeds. No cuts were made to ryegrass throughout the cycle, nor any fertilizer was applied to the winter crop.

On 27 Oct. 2017, phytosociological evaluations of the weed communities present in the treatments were carried out. The sampling method adopted for surveying the weed occurrence was that of the Random Quadrats, as proposed by Barbour et al. (1998), being randomly sampled one quadrat per plot (n = 8), with 0.25 m of side. In the quadrat area, fleabane (*Conyza* spp.), fringerush (*Fimbristylis* sp.), Ryegrass (*Lolium multiflorum*) and beardgrass (*Polypogon* sp.), which predominated in the area, were quantified; the other weed species reported, were grouped as "others". Plants were cut to the soil level, packed in paper bags by species, and dried into forced air circulation oven at ± 75 ºC for three days, for later dry mass measurement. The number of plants (number m^{-2}) and its total dry mass (g m^{-2}) for each weed species (absolute infestation) were presented in histograms as a function of treatment, with the respective sampling standard errors.

The areas were intra analyzed by the diversity coefficients of Simpson (D) and Shannon-Weiner (H') (Barbour et al., 1998). The sustainability coefficient (SEP) was also estimated according to McManus and Pauly (1990).

All coefficients and graphs were obtained in the statistical environment R (R Development, 2017).

Results and discussion

In general, herbicide application, independent of the cropping system, reduced weed density of the monitored species by almost half, compared to the non-application treatments (Figure 1). However, regarding the no-tillage system, infestation levels and dry mass of the species were equivalent in treatments with and without herbicide application. This illustrated how important is the mulching supplied by a winter crop to suppress weed infestation in rice.

The largest volume of dry mass deposited on the soil surface in the no-till system seems to have performed two functions; in the area without herbicide application (semi-ecological management), this straw was responsible for avoiding or at least reducing the access of weed seeds and seedlings to light (Silva et al., 2013; Teófilo et al., 2012; Silva et al., 2009), which contributed to a lower success rate in its establishment in the area. In treatments with herbicides, besides the effect of shading, this straw may have been responsible also for capturing part of the applied herbicide and caused possible losses because, when the herbicide is retained in the straw it becomes more exposed to the environment, being subjected to transportation and degradation processes (Iupac, 2017). This may have caused somehow a reduction in weed control in the previous year with the application of herbicides to the no-till system, compared to other systems (Figure 1).

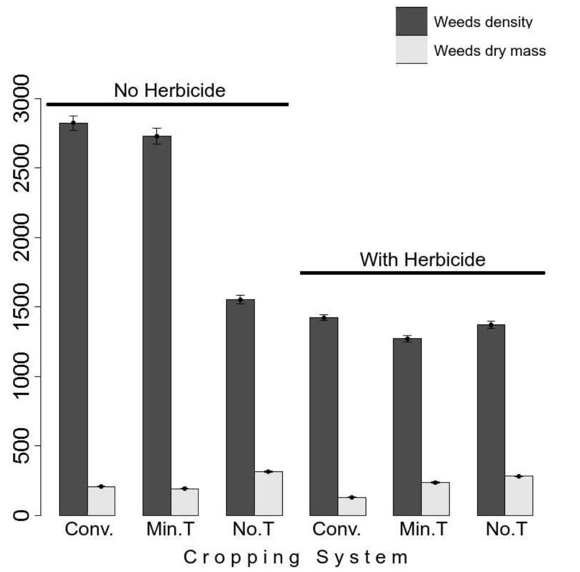

Figure 1. Infestation density samplings (nº m^{-2}) and dry mass (g m^{-2}) of weed species in Conventional cropping system, Minimum cropping system and No-tillage system, when non-applied and applied herbicides. Embrapa Clima Temperado, Pelotas-RS, 2017

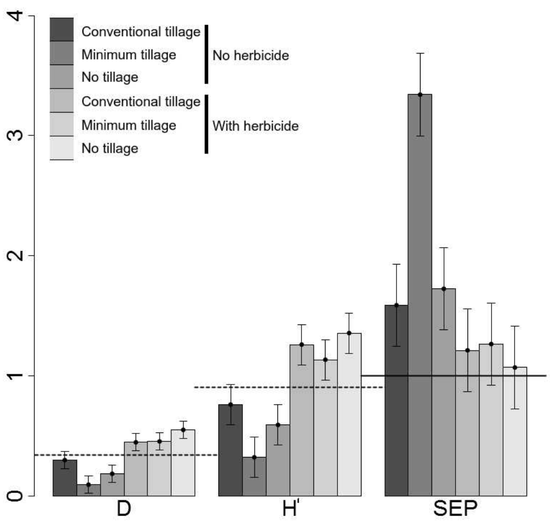

Figure 2. Indices of species diversity. Weed species diversity, D = Simpson diversity index; H' = Shannon-Weiner diversity index; SEP= Shannon-Weiner Evenness Proportion. Embrapa Clima Temperado, Pelotas-RS, 2017.

Both Simpson and Shannon-Weiner diversity indexes, with herbicide application, were generally higher than treatments without application (Figure 2). Weeds reported in the area with herbicide management, independent of the cropping system, were very likely to have equivalent susceptibility to the applied herbicides, which resulted in inhibition and similar levels of occurrence. However, for the treatments without application, the low diversity index expresses the predominance of only some species with greater competitive ability, which, by shading and inhibiting the other weeds, ended up taking over most of the available area.

In the semi-ecological treatments (without herbicides), the conventional system presented D and H' diversities superior to the minimum and no-till systems, which may be related to the fact that, during the crop cycle in the conventional system, there was less area coverage and after soil tillage in the following year, there was a higher number of weeds, due to the lower competitive intensity among the species. According to Lindquist; Maxwell (1991) and Guersa; Martinéz-Guersa (2000), the conventional tillage tends favor persistent soil weed seed banks, since it incorporates and distributes seeds uniformly in the soil profile, and this distribution is influenced by the frequency of tillage.

In the area with herbicide treatments, SEP was equivalent to environmental stability (SEP ~ 1), according to the standard errors (Figure 2). This probably results from the supposed similarity in sensitivity of the weed species present to the herbicides applied in the previous year, which may have caused equalization in the occurrence of the species in terms of number of individuals and accumulation of dry mass, as well as seed production. In the no-herbicide area, the behavior observed in the minimum tillage may be highlighted, where the small number of species observed and the exaggerated predominance of certain species, resulted in low values of D and H' and high SEP (Figure 2). The latter reflects the disproportionate accumulation of dry mass in the predominant weeds compared to their number of individuals. In other words, the environment has very high levels of certain factors that are demanded in great quantity by some species; these privileged species have developed exaggeratedly dominating the area and inhibiting the occurrence of other species.

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Characterization of the Weed Flora in Rice Areas under Distinct Cropping Systems and Herbicide Managements

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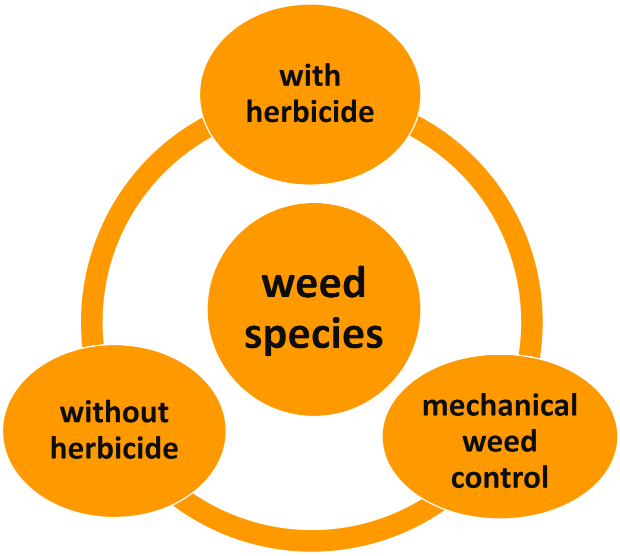
Introduction



Objective

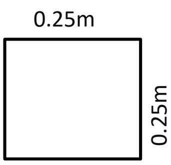
To evaluate the incidence of weeds in flooded rice areas, in the pre-planting of the summer crop, as a function of the planting system and the use of herbicides in the previous cropping year.

Material and Methods

Locality:

Factors:
A: herbicide application (traditional and semi-ecologic)
B: planting system (conventional, minimum cultivation, no-till)
Variety: rice cv. Guri Inta CL
Spacing: 0.175 m
Fertilization: 300 kg ha^{-1} of N-P-K 5-25-25

Phytosociological evaluations of the weed communites present in the treatments were carried out. The sampling method adopted for surveying the weed occurrence was that of the Random Quadrats, as proposed by Barbour et al.(1998)



The areas were also intra analyzed by the diversity coeficients of Simpson (D) and Shannon-Weiner (H') (Barbour et al., 1998). The sustainability coeficient (SEP) was also estimated according to McManus and Pauly (1990).

Results

In general, herbicide application, independent of the cropping system, reduced weed density of the monitored species by almost half, compared to the non-application treatments (Figure 1). However, regarding the no-tillage system, infestation levels and dry mass of the species were equivalent in treatments with and without herbicide application. This illustrated how important is the mulching supplied by a winter crop to suppress weed infestation in rice.

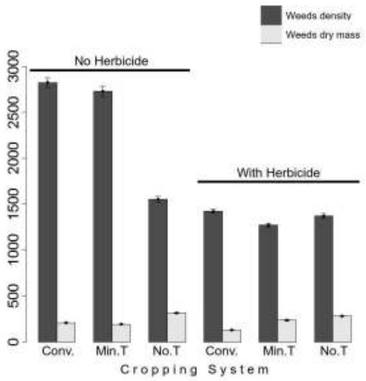


Figure 1. Infestation density samplings (nº m-2) and dry mass (g m-2) of weed species in Conventional cropping system, Minimum cropping system and No-tllage system, when non-applied and applied herbicides. Embrapa Clima Temperado, Pelotas-RS, 2017

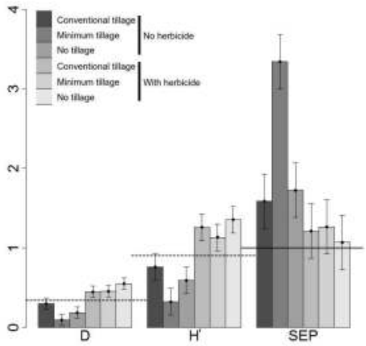


Figure 2. Indices of species diversity. Weed species diversity, D = Simpson diversity index; H' = ShannonWeiner diversity index; SEP= Shannon-Weiner Evenness Proportion. Embrapa Clima Temperado, Pelotas-RS, 2017

Both Simpson and Shannon-Weiner diversity indexes, with herbicide application, were generally higher than treatments without application (Figure 2). Weeds reported in the area with herbicide management, independent of the cropping system, were very likely to have equivalent susceptibility to the applied herbicides, which resulted in inhibition and similar levels of occurrence. However, for the treatments without application, the low diversity index expresses the predominance of only some species with greater competitive ability, which, by shading and inhibiting the other weeds, ended up taking over most of the available area.

In the semi-ecological treatments (without herbicides), the conventional system presented D and H' diversites superior to the minimum and no-till systems, which may be related to the fact that, during the crop cycle in the conventional system, there was less area coverage and afer soil tillage in the following year, there was a higher number of weeds, due to the lower competitive intensity among the species.

Conclusions

The environment has very high levels of certain factors that are demanded in great quantity by some species; these privileged species have developed exaggeratedly dominating the area and inhibitng the occurrence of other species. These species are yet to be identified.

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Weed Flora in Rice Areas under Distinct Cropping Systems, Herbicide and Irrigation Managements

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Abstract: the aim of the present study was to evaluate the incidence of weeds in the pre-planting of the summer crop as a function of the planting system, herbicide use and irrigation management. The experiment was installed in field conditions, in randomized complete blocks design, and 3 x 2 factorial scheme with eight replications. Treatments consisted in submitting rice to three management factors, as follows: water management – continuously flooded or intermittend irrigation (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B), and planting system – conventional soil tillage, minimum tillage and no-till systems (Factor C). One year after rice cultivation, preceding the planting of the next cropping season, phytosociological evaluations of the weed communities present in the treatments were carried out. We assessed the overall infestation level and weed species composition, which were classified by their respective density, frequency and dominance abilities. In flood-irrigated rice cultivation, the no-till planting system provides the lowest levels of weed infestation; the chemical control leads to the selection of resistant or tolerant herbicide species, such as *Polypogon* sp.; both continuous and intermittent water management systems did not cause significant changes in the level of infestation and weed composition temperate rice areas.
Keywords: phytosociology, *Oryza sativa,* crop management.

Introduction

Management systems as well as agricultural practices interfere on the agroecological dynamics of weed growth and dispersal; the weed community may vary according to the cultural practices applied to the area, and their identification become indispensable to avoid crop grain yield losses by subsidizing the choice for the most adequate control method (NORDI and LANDGRAF, 2009).

Lack of knowledge on existing weed species in a given crop, coupled to the inadequate use of control methods, often result in the excessive use of herbicides, increasing both the environmental risk an the economical cost of the field. In this sense, the identification an quantification of these species becomes necessary to the proper selection of control methods (Silva et al., 2015).

In rice, the conventional planting system is usually adopted, but recently the minimum soil tillage in being vastly adopted; in this system, soil tillage occurs right after the harvest of the field, and a simple burndown operation is applied prior to planting, on the next cropping season. Weeds on the soil seed bank may be stimulated to germinate due to this late season soil tillage. Irrigation management is another issue of concern for weed occurrence in rice, since the rice cropping system in Southern Brazil comprehends a definitive flooding of the area to be imposed from rice tillering start onwards. Alternative management systems aiming to save water are being tested; among them, the intermittent irrigation is gaining importance.

For Pitelli (2000), phytosociological indexes support the analysis impacts caused by differential management systems and agricultural practices on the dynamics of weed communities in cropped fields, subsidizing the decision on the herbicides to be applied.

Therefore, the aim of the present study was to evaluate the incidence of weeds in the pre-planting of the summer crop as a function of the planting system, herbicide use and irrigation management.

Material and methods

The experiment was installed in field conditions, at Embrapa Clima Temperado, Pelotas-RS, Brazil, in randomized complete blocks design, and 3 x 2 factorial scheme with plots measuring 4 m x 4 m, with eight replications.

Treatments consisted in submitting rice to three management factors, as follows: water management – continuously flooded or intermittend irrigation (Factor A), coupled to the application (traditional control) or not (semi-ecological system) of herbicides (Factor B), and planting system – conventional soil tillage, minimum tillage and no-till systems (Factor C). Seeding was carried out with nine rows spaced in 0.175 m, on 09 Nov. 2016 with 100 kg ha^{-1} of the variety Guri Inta CL. The basic fertilization applied at the planting furrow consisted of 300 kg ha^{-1} of N-P-K 5-25-25.

For the planting system, in the conventional system, the area underwent plowing and disking prior to planting. In the minimum cultivation, the area underwent two light diskings, 20 days before planting rice. For no-till, the vegetation mulching was burndown 20 days prior to planting rice.

As for the chemical treatments, those without herbicide did not receive any application, not even for burndown prior to planting; the natural area mulching was only accommodated closer to soil by the planting operations. In plots where herbicides were to be applied, the area was burndown 20 days before planting, with 1440 g ha^{-1} of glyphosate. Subsequently, 73.5 g ha^{-1} of imazapyr + 24.5 g ha^{-1} of imazapic (140 $g_{c.p.}$ ha^{-1} of Kifix) + 400 g ha^{-1} de clomazone were applied right after rice planting. Thirty-five days after emergence, the application of 375 g ha^{-1} of quinclorac was necessary for control of jointvetch (*Aeschynomene* spp.).

Flood irrigation was established on 08 Dec. 2016, 20 days after crop emergence, at the beginning of tillering (~ V3), by establishing a water layer of 7 cm, which was maintained throughout the cropping cycle in treatments continuously flooded. In treatments with intermittent irrigation, water was replenished only when about 20% of the soil was under no water layer. After harvesting, in April 2017, ryegrass (*Lolium multiflorum*) was established as winter cover at rate of 25 kg ha^{-1} of seeds. No cuts were made to ryegrass throughout the cycle, nor any fertilizer was applied to the winter crop.

On 27 Oct. 2017, phytosociological evaluations of the weed communities present in the treatments were carried out. The sampling method adopted for surveying the weed occurrence was that of the Random Quadrats, as proposed by Barbour et al. (1998), being randomly sampled one quadrat per plot (n = 8), with 0.25 m of side. In the quadrat area, fleabane (*Conyza* spp.), fringerush (*Fimbristylis* sp.), Ryegrass (*Lolium multiflorum*) and beardgrass (*Polypogon* sp.), which predominated in the area, were quantified; the other weed species reported, were grouped as "others". Plants were cut to the soil level, packed in paper bags by species, and dried into forced air circulation oven at ± 75 ºC for three days, for later dry mass measurement. The number of plants (number m^{-2}) and its total dry mass (g m^{-2}) for each weed species (absolute infestation) were presented in histograms as a function of treatment, with the respective sampling standard errors.

The absolute infestation data set was tested for normality by the Shapiro-Wilk test, prior to estimating the density (based on number of individuals), the frequency (based on the spatial distribution of the species) and the dominance (based on capacity to accumulate mass) in relative terms, which were used to obtain the importance value for each species in each factor / treatment, according to and Barbour et al. (1998)

All formulas and procedures, both for sampling and for describing the communities as well as species grouping, followed the recommendations by Barbour et al. (1998) for synecological analyzes.

Results and discussion

Factor A – Cropping System

Due to the high importance values (IV), the most favored weeds were *Fimbristylis* sp., *Lolium multiflorum* and *Polypogon* sp., with no remarkable differences between cropping systems (Table 1). *Conyza* sp. was less evident in the minimum tillage compared to the other systems, due to inherent characteristics of the species, as pointed ou by CONCENÇO & CONCENCO (2016); on the one hand, this species is relatively sensitive to soil disturbance, which supports its greater occurrence in no-till. By being highly prolific, *Conyza* sp. occupies the available space, just as reported for the conventional tillage. In the minimum tillage, the small soil disturbance associated to the presence of straw cover ended up by reducing its occurrence.

Table 1. Density, frequency, dominancy and important value of weed species in Conventional cropping system, Minimum cropping system and No-tillage system. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Conventional cropping system			
Species	**de**	**fr**	**do**	**vi**
Conyza sp.	0.42	10.91	0.83	4.05
***Fimbristylis* sp.**	1.04	16.36	9.74	9.05
L. multiflorum	78.66	29.09	67.26	58.34
***Polypogon* sp.**	4.33	18.18	11.59	11.37
Others	15.54	25.45	10.57	17.19
	Minimum cropping system			
Conyza sp.	0.2	4.55	0.31	1.69
***Fimbristylis* sp.**	0.85	25	9.74	11.86
L. multiflorum	86.7	36.36	65.91	62.99
***Polypogon* sp.**	8.35	15.91	14.81	13.02
Others	3.9	18.18	9.23	10.44
	No-tillage system			
Conyza sp.	0.27	8	1.41	3.23
***Fimbristylis* sp.**	2.05	16	6.93	8.33
L. multiflorum	75.51	32	66	57.84
***Polypogon* sp.**	14.09	16	16.45	15.51
Others	8.07	28	9.21	15.09

In general terms, the no-till and the conventional systems were similar in terms of species diversity, while the minimum tillage differed; the latter seems to have not contributed for neither the elimination of the weeds present, nor the emergence of new weeds (Table 1).Cruz et al. (2009) reported that areas rotated with soybean, maize and irrigated rice in no-till, under central pivot irrigation, showed greater weed diversity. Thus, it can be hypothesized that crop rotation, succession and tillage system diversity contribute for adequate diversity and sustainability into a cropping system. The data corroborate with Ceolin et al. (2016), who reported that ryegrass, planted as winter cover crop in rice growing areas, was efficient in reducing weed occurrence. In flooded rice areas without crop rotation (rice / fallow) for more than five years, Erasmo et al. (2004) found higher prevalence of weeds from Poaceae and Asteraceae families. When rotated with soybeans, Cyperaceae also took importance.

The germination flow of weeds under no-till is mainly due to changes in soil temperature and moisture, since there is no disturbance that could stimulate germination of certain species. During winter, reduced soil temperature favors hibernal weeds, while estival species are favored during the warmer cropping season (Gomes et al., 2008).

In general terms, the cropping system does not seem to be the main factor in the definition of weeds occurring in lowland rice areas, since the importance values for the monitored species and also for the other species present in the areas were very similar between the three soil tillage systems (Table 1). This was corroborated by the similarity analysis (data not shown), which indicated J = 100% among all treatments, regarding exclusively species composition. As expected, ryegrass predominated because it was an introduced species, which may have contributed to the suppression of weeds and the equalization of infestation between the different systems.

Comparing crop production systems, Pacheco et al. (2016) verified that for rice preceded by soybean in the summer and *Pennisetum glaucum* in winter, the conventional system resulted in fewer weeds established in the area during rice cultivation, compared to no-till. The author attributed the fact to poor soil cover provided by *P. glaucum*. Therefore, the no-till system seems to be efficient in weed suppression only if there is efficient soil cover and adequate straw volume, which can be achieved by additional sowing of some winter cover crop such as ryegrass. This is one of the few cover / grazing species adapted to floodplain environments, achieving high yields of dry mass with small addition of nitrogen. It presents high nutrient cycling capacity, which justifies its use prior to rice cultivation, besides being suitable for both for soil cover and animal grazing (CORREIA, et al., 2013).

Factor B – Herbicide Application

Regarding the phytosociological characterization, ryegrass showed higher values compared to the other species, most probably because it was planted on purpose, for both treatments (with and without herbicide) (Table 2). *Fimbristylis* sp. and the other unidentified species, were more affected by herbicide residuals, showing reduction in all indices evaluated. However, by eliminating some species, others end up occupying the space, such as *Conyza* sp. and *Polypogon* sp., which were favored in treatments under herbicide applications. This advantage can be attributed to the fact that these species may present a certain tolerance to the herbicide, or even resistance, as in the case of *Conyza* sp. to glyphosate (TREZZI, et al., 2011).

Table 2. Density, frequency, dominancy and important value of weed species when non-applied and applied herbicides. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Non-applied herbicide				Applied herbicide			
Species	**de**	**fr**	**do**	**vi**	**de**	**fr**	**do**	**vi**
Conyza sp.	0.17	5.56	0.25	1.99	0.54	10.26	1.66	4.15
***Fimbristylis* sp.**	1.27	29.17	11.61	14.02	1.18	10.26	5.08	5.51
L. multiflorum	88.71	33.33	74.76	65.6	66.75	30.77	56.91	51.48
***Polypogon* sp.**	0.28	5.56	0.49	2.11	22.38	26.92	30.48	26.59
Others	9.57	26.39	12.89	16.28	9.15	21.79	5.87	12.27

Factor C- Irrigation Management

Continuous and intermittent irrigation managements were very similar in density, frequency and dominance of the evaluated species (Table 3). It is proposed that, under flood conditions, competitive strategies based on dominance tend to be preponderant for success in establishment of a certain weed species.

Table 3. Density, frequency, dominancy and important value of weed species in continuous and intermittent water management. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Continuous Management					Intermittent Management			
Species	**de**	**fr**	**do**	**vi**	**Species**	**de**	**fr**	**do**	**vi**
Conyza sp.	0.33	20	0.87	7.07	***Conyza sp.***	0.28	20	0.97	7.08
Fimbristylis sp.	1.43	20	7.95	9.79	***Fimbristylis sp.***	1.05	20	9.11	10.05
L. multiflorum	79.7	20	67.8	55.84	***L. multiflorum***	81.66	20	64.69	55.45
Others	9.91	20	9.64	13.18	**Others**	8.94	20	9.47	12.8
Polypogon sp.	8.6	20	13.8	14.12	***Polypogon sp.***	8.07	20	15.76	14.61

Conclusions

In flood-irrigated rice cultivation, the no-till planting system provides the lowest levels of weed infestation. The application of herbicides in flooded rice crops reduces weed infestation levels, compared to areas without the application of weed management methods. However, chemical control leads to the selection of resistant or tolerant herbicide species, such as *Polypogon* sp. Both continuous and intermittent water management systems did not cause significant changes in the level of infestation in rice areas.

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Weed Flora in Rice Areas under Distinct Cropping Systems, Herbicide and Irrigation Managements

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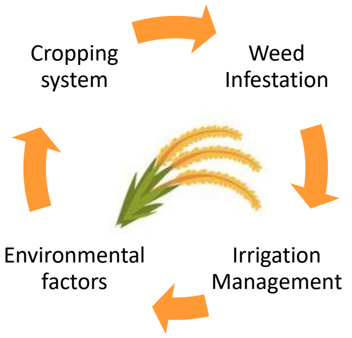
Introduction

Rice is one of the most important cereals produced in the world. In Brazil, Rio Grande do Sul (RS) and Santa Catarina (SC) States being responsible for approximately 80% of the brazilian production.



Management systems as well as agricultural practices interfere on the agroecological dynamics of weed growth and dispersal.

Objective

The aim of the present study was to evaluate the incidence of weeds in the pre-planting of the summer crop as a function of the planting system, herbicide use and irrigation management.

Material and Methods

- The experiment was installed in field conditions, at Embrapa Clima Temperado, Pelotas-RS, Brazil.
- Seeding was carried out with nine rows spaced in 0.175 m, on 09 Nov. 2016 with 100 kg ha^{-1} of the variety Guri Inta CL.

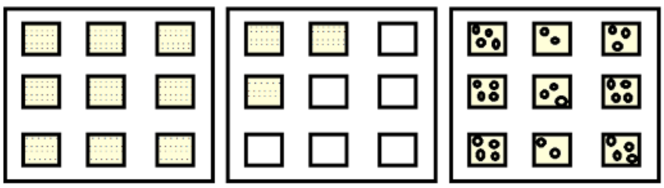
Treatments

FACTOR A
Cropping System
- Conventional cropping system
- Minimum cropping system
- No-tillage system

FACTOR B
Herbicide Application
- Non-applied herbicide
- Applied herbicide (Kifix® + clomazone+ quinclorac)

FACTOR C
Irrigation Management
- Continuous Management
- Intermittent Management

- The overall infestation level and weed species composition, were classified by:



Density **Frequency** **Dominance**

- All formulas and procedures, both for sampling and for describing the communities as well as species grouping, followed the recommendations by Barbour et al. (1998) for synecological analyzes.

Results

Table 1: Density, frequency, dominance and important value of weed species in Conventional cropping system, Minimum cropping system and No-tillage system. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Conventional cropping system			
Species	de	fr	do	vi
Conyza sp.	0.42	10.91	0.83	4.05
Fimbristylis sp.	1.04	16.36	9.74	9.05
L. multiflorum	78.66	29.09	67.26	58.34
Polypogon sp.	4.33	18.18	11.59	11.37
Others	15.54	25.45	10.57	17.19
	Minimum cropping system			
Conyza sp.	0.2	4.55	0.31	1.69
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L. multiflorum	86.7	36.36	65.91	62.99
Polypogon sp.	8.35	15.91	14.81	13.02
Others	3.9	18.18	9.23	10.44
	No-tillage system			
Conyza sp.	0.27	8	1.41	3.23
Fimbristylis sp.	2.05	16	6.93	8.33
L. multiflorum	75.51	32	66	57.84
Polypogon sp.	14.09	16	16.45	15.51
Others	8.07	28	9.21	15.09

In general terms, the cropping system does not seem to be the main factor in the definition of weeds occurring in lowland rice areas, since the importance values for the monitored species and also for the other species present in the areas were very similar between the three soil tillage systems.

Table 2: Density, frequency, dominance and important value of weed species when non-applied and applied herbicides. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Non-applied herbicide				Applied herbicide			
Species	de	fr	do	vi	de	fr	do	vi
Conyza sp.	0.17	5.56	0.25	1.99	0.54	10.26	1.66	4.15
Fimbristylis sp.	1.27	29.17	11.61	14.02	1.18	10.26	5.08	5.51
L. multiflorum	88.71	33.33	74.76	65.6	66.75	30.77	56.91	51.48
Polypogon sp.	0.28	5.56	0.49	2.11	22.38	26.92	30.48	26.59
Others	9.57	26.39	12.89	16.28	9.15	21.79	5.87	12.27

Table 3: Density, frequency, dominance and important value of weed species in continuous and intermittent water management. Embrapa Clima Temperado, Pelotas-RS, 2017.

	Continuous Management				Intermittent Manage-ment				
Species	de	fr	do	vi	Species	de	fr	do	vi
Conyza sp.	0.33	20	0.87	7.07	*Conyza sp.*	0.28	20	0.97	7.08
Fimbristylis sp.	1.43	20	7.95	9.79	*Fimbristylis sp.*	1.05	20	9.11	10.05
L. multiflorum	79.7	20	67.8	55.84	*L. multiflorum*	81.66	20	64.69	55.45
Others	9.91	20	9.64	13.18	Others	8.94	20	9.47	12.8
Polypogon sp.	8.6	20	13.8	14.12	*Polypogon sp.*	8.07	20	15.76	14.61

Conclusions

In general terms, the cropping system does not seem to be the main factor in the definition of weeds occurring in lowland rice areas. The application of herbicides in flooded rice crops reduces weed infestation levels and about the management irrigation, under flood conditions, competitive strategies based on dominance tend to be preponderant for success in establishment of a certain weed species.

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4 *Breeding and grain quality*

The effect of water saving practices on rice grain quality in south eastern Australia

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Abstract

Water availability is a significant issue in rice-producing regions that are entirely dependent on irrigation and has led to the development of water saving (WS) techniques. Delayed permanent water (DPW) and delayed permanent water with a post flower flush (DPW+PFF) are WS methods suitable for temperate areas such as south eastern Australia. Currently, the impact of DPW and DPW+PFF on rice grain quality in south eastern Australia is poorly understood. We compared the effect of DPW and DPW+PFF with conventional irrigation methods on grain development and quality over three years. These data revealed at N rates above 60 kg N ha^{-1}, head rice yield (HRY; the proportion of whole grain expressed as a percentage of harvested grain) was higher in the water saving irrigation treatments compared to conventional irrigation techniques for all varieties. Monitoring of grain filling behaviour revealed water stress during the vegetative period (DPW and DPW+PFF) reduces the grain-filling duration. However, extends grain maturation (100% flowering to 18-22% grain moisture) which had a significant positive correlation with HRY. These data indicate that water stress during the vegetative stage influences grain-filling behaviour, which improves grain quality.

Key words: rice grain quality, delayed permanent water, head rice yield

The effect of nitrogen rate and timing on rice grain quality in south eastern Australia

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Abstract

In south-eastern Australia, the total nitrogen fertiliser (N) rate is often split into two applications to reduce the risk of sterility induced by cold temperatures and high N uptake. This strategy involves a basal N application applied pre-permanent water (PW) and the second dose following panicle initiation (PI). Previous research demonstrates that split N application (Pre-PW and PI) affects crop yield, however, data investigating the impact on grain quality is relatively sparse. Using a medium-grain rice variety, we compared the effect of eight N treatments (Five N rates applied pre-PW and three split treatments with the same total N rate) on grain quality parameters and protein composition. These data revealed increasing the rate of N applied pre-PW significantly increased head rice yield (HRY; the proportion of whole grain expressed as a percentage of harvested grain), however, splitting the same total N rate into two applications reduced HRY. HRY decreased as the rate of the first N dose decreased and the second dose increased. This trend also occurred for RVA setback with the split N treatments producing a more negative setback than the pre-PW N treatments. Analysis of protein composition releveled changes in HRY and RVA setback occurred due to changes in protein composition from N application. These results indicate that altering the nutritional management of rice changes the protein composition affecting grain quality parameters.

Key words: rice grain quality, head rice yield, protein, nitrogen fertiliser, RVA setback

Department of Primary Industries

The effect of nitrogen fertiliser rate and timing on rice grain quality in south eastern Australia

R.M. Wood[1], B.W. Dunn[2] , D.L.E Waters[3], C.L. Blanchard[4] & P. Oli[5]

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Introduction

In south-eastern Australia, the total N rate is often split into two applications to reduce the risk of sterility induced by cold temperatures and high N uptake. This strategy involves a basal N application applied pre-permanent water (PW) and the second application following panicle initiation (PI). While previous research demonstrates that split N application (pre-PW and PI) affects crop yield, data investigating the impact on grain quality is relatively sparse.

Figure 1: Nitrogen Trial at Yanco Agricultural Institute, NSW Department of Primary Industries

Materials and Methods

The medium-grain, Viand[φ], was grown using 8 nitrogen treatments (Fig. 1). Five pre-PW N treatments (0, 60, 90, 120 & 150 kg N/ha) applied at the 4-leaf crop growth stage. Three N treatments (30-90, 60-60 & 0-120 kg N/ha) received a total of 120kg N/ha split into two doses applied at pre-PW and within five days of PI. Samples were harvested at maturity (19-22% moisture). **Head rice yield (HRY)** = the proportion of unbroken grain expressed as a percentage of harvested grain. Ground samples were used to determine the amylose, total protein and protein composition.

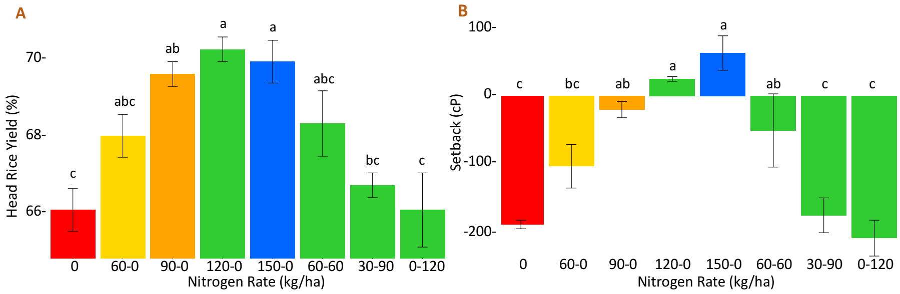

Figure 2: (A) Head Rice Yield percentage (HRY) and **(B)** RVA setback (Final viscosity minus peak viscosity) as affected by nitrogen fertiliser rate and timing. Left number is the rate applied pre-permanent water and right number is the rate applied at panicle initiation. Colour represents total nitrogen rate (i.e. green is 120 kg N/ha). Different letters indicate significant differences ($p < 0.05$).

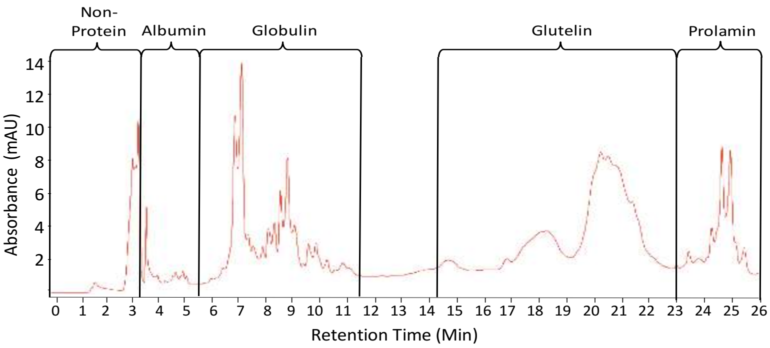

Figure 3: Rice protein fractions measured using High Performance Liquid Chromatography (HPLC).

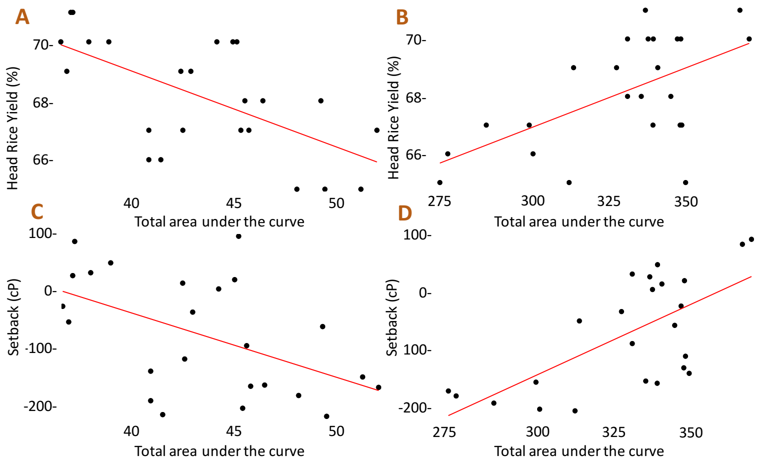

Figure 4: Regression analysis of Head Rice Yield and RVA setback vs. **(A+C)** total albumin content and **(B+D)** total globulin content.

Results

- Increasing the nitrogen rate applied pre-PW significantly increased HRY and RVA setback (Fig. 2).
- Splitting the same N rate (120kg/ha) into two applications reduced HRY and RVA setback (Fig. 2).
- Both parameters decreased as the rate of the first N dose decreased and the second increased.
- No significant difference in amylose and total protein content between N treatments was found, excluding protein in the 0N rate.
- RVA setback was more highly correlated with HRY (r = 0.9, $p < 0.01$) than total protein content (r = 0.53, $p < 0.05$).
- Analysis of protein fractions using HPLC (Fig. 3) revealed globulin (r = 0.57, $p < 0.05$) and glutelin (r = 0.43, $p < 0.05$) were positively correlated with N uptake at PI.
- The albumin proportion of total protein was negatively correlated (r = -0.7, $p < 0.05$) with N uptake at PI.
- When comparing the N treatments with a total N rate of 120kg/ha:
  - Increasing the N rate applied at PI increased the prolamin proportion of total protein.
  - Increasing the total prolamin content decreased the globulin proportion of total protein (r = -0.66, $p < 0.05$).
- Albumin and globulin showed significant correlations with HRY and RVA setback:
  - Albumin was negatively correlated with both HRY (r = -0.62, $p < 0.05$; Fig. 4 A) and RVA setback (r = -0.51, $p < 0.05$; Fig. 4 C).
  - Globulin was positively correlated with both HRY (r = 0.58, $p < 0.05$; Fig. 4 B) and RVA setback (r = 0.67, $p < 0.05$; Fig. 4 D)

Summary and conclusion

- Increasing the pre-PW N rate increasing the synthesis of globulin and glutelin reducing the albumin proportion within the grain. The increase in globulin increased HRY and RVA setback.
- Increasing the N rate applied after PI increases the synthesis of albumin and prolamin. The increase in albumin decreased HRY and setback.
- Altering the nutritional management of rice changes the protein composition, affecting grain quality parameters.

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Understanding the quality factors that impact the rice price

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ABSTRACT

The quality traits of rice are key factors that impact the price of rice traded on both domestic and international markets. Fragrant rice commands the highest prices, and then factors such as the proportion of chalky and broken grains decrease the price incrementally as the amount of those grains increases. By understanding more deeply, the factors that maximize aroma and minimize broken and chalky grains would enable these to be managed along the value chain from breeding programs to rice traders. The objective of this project is to understand more deeply how these factors impact quality, and to investigate each factor to determine how it can be controlled to impact positively on the price of rice. For the first time, technology enables us to sort broken and chalky grains to determine their quality and the impact on sensory and processing quality, the omics platforms enable the discovery of genes that impact the amount of aroma. This presentation will describe how we can increase the value of rice by understanding the impact of chalk and broken rice on quality, and ways to increase the amount of aroma in the grains.

Key words: rice price, aroma, chalk, broken grains

ADDITIVE MAIN EFFECTS AND MULTIPLICATIVE INTERACTION (AMMI) ANALYSIS OF GRAIN YIELD STABILITY OF ADVANCE RICE GENOTYPES IN GUYANA

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Rice (*Oryza sativa* L.) has been cultivated as a major cereal crop for over 7,000 years in many parts of the world. It serves as primary food crop and a major sources income for persons in the developing countries. In order to fulfill the daily consumptions and dietary intake of nearly one billion people of the world there is the need to develop and produce stable high yielding cultivars. In view of this, fifteen advanced rice germplasm entries along with three check varieties were assessed for grain yield stability under six environment in Guyana. The trials conducted in spring and autumn seasons of 2018. A randomized block complete block design with three replication was employed. AMMI analysis was employed to study the genotype and environment interactions. The average grain yield of the 18 genotypes range from 5504.44 to 7499.21 Kg/ha with a greater proportion of the genotypes showed more stable grain yield and lesser proportion showed higher grain yield status. The biplot results of the two seasons at three locations showed the consistent expression of high stable grain yield performance of genotype FG12-259; followed by FG12-23, FG12-49, FG14-43, G13-126, G15-11, G14-10 and G16-104. Likewise, AMMI analysis found environment at Rice Research Station, Burma, Region # 5, Spring crop, 2018 (E2) and Anna Regina, Region # 2, Autumn crop, 2018 (E4) were observed to be the most representative environment. The biplot showed clearly the smaller average -

environment axis (AEA) angle and closeness to the ideal test environment of E2 and E4. Also, Anna Regina, Region # 2, Autumn crop, 2018 (E4) followed by Lesbeholden, Black Bush Polder, Region # 6, Autumn crop, 2018 (E6) recorded a low IPCA1 scores and showed small interactions. Also, genotypes spreading further away from the origin showed greater stable grain yield status and contributed more to both GEN and G x E. Those were the most important genotypes from plant breeder's prospective. The what-won-where biplot pattern suggested the target environment consisted of three mega-environment, since four environment falls in one sector and one each in another two sectors. The three check cultivars GRDB 10 GRDB 12 and GRDB14 also expressed similar higher level of stable grain yields over all test environment.

Keywords: AMMI analysis; biplot; Stable grain yield; advance genotypes; genotype by environment interaction.

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ADDITIVE MAIN EFFECTS AND MULTIPLICATIVE INTERACTION (AMMI) ANALYSIS OF GRAIN YIELD STABILITY OF ADVANCE RICE GENOTYPES IN GUYANA

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Introduction

Rice (*Oryza sativa* L.) has been cultivated as a major cereal crop for over 7,000 years in many parts of the world.
It serves as primary food crop and a major sources income for persons in the developing countries.
In order to fulfill the daily consumptions and dietary intake of nearly one billion people of the world there is the need to develop and produce stable high yielding cultivars.

Objective

To evaluate and assess grain yield stability of fifteen advance rice germplasm under six environment in Guyana

Material and Methods

- The trials conducted at Anna Regina in Region # 2; Rice Research Station, Burma in Region # 5 and Lesbeholden, Black Bush Polder in Region # 6 during the spring and autumn seasons of 2018 .
- A randomized block complete block design with three replication was employed.
- Fifteen advance rice germplasm lines along with three local checks were evaluated (Table 1).
- The Additive Main and Multiplicative Interaction (AMMI) analysis was employed to study the genotype and environment interactions using MATMODEL version 3.0 (Gauch 2007) and Plant Breeding Tools Version 1.4 (PBTools 2014).

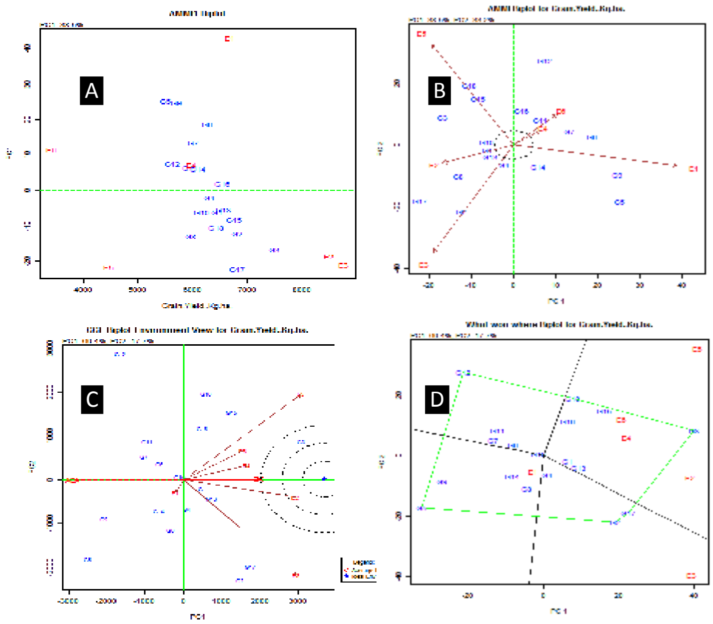
Figure 1. Display of trial at Rice Research Station, Burma in Region # 5

Table 1. List of germplasm lines and check.

S.N.	Strain	Designation
G1	FG12-23	FL10891-13P-4-3P-1P-M
G2	FG12-49	FL10915-2P-4-2P-1P-M
G3	FG12-259	FL10919-10P-5P-3P-1P-M
G4	G14-10	GR1630-40-47-2-1-1-1
G5	G15-02	GR1538-1-30-4-3-1-1-1-1-2
G6	G15-11	GR1627-31-27-3-1-1-1-2-1
G7	FG15-01	FL12017-2P-4-1P-1P-M
G8	FG15-02	FL12032-2P-6-1P-2P-M
G9	G16-102	GR 1621-25-6-9-3-1-1-1-1-1-1-1
G10	G16-104	GR 1629-33-66-2-2-1-1-2-1-1-2
G11	G16-108	GR 1708-54-6-1-1-1-5-1-1-2
G12	G16-112	GR 1739-1-77-1-3-1-1
G13	FG14-43	FL13033-5P-4SR-1P-1P-M-M
G14	FG15-35	FL14026-1P-3SR-2P-1P-M-MP
G15	G13-126	GR 1584-47-8-2-2-1-1
G16	GRDB 10	
G17	GRDB 12	
G18	GRDB 14	

Results

The average grain yield of the 18 genotypes range from 5504.44 to 7499.21 Kg/ha with a greater proportion of the genotypes showed more stable grain yield and lesser proportion showed higher grain yield status.



Notes: G= Genotype; E= Environment; E1 - Anna Regina, Region # 2 (Spring crop, 2018); E2 - Rice Research Station, Burma, Region # 5 (Spring crop, 2018); E3 - Lesbeholden, Black Bush Polder, Region # 6 (Spring crop, 2018); E4 - Anna Regina, Region # 2 (Autumn crop, 2018); E5 - Rice Research Station, Burma, Region # 5 (Autumn crop, 2018); E6 - Lesbeholden, Black Bush Polder, Region # 6 (Autumn crop, 2018)

Figure 2. A. AMMI1 Biplot display mean grain yield (Kg/ha) and IPCA 1 scores; B. Display of first and second principal component axis (IPAC 1 vs. IPAC 2); C. Shows the mean performance, ideal environment and stability of the genotype and D. Show which genotype performed best in which environments- of the 18 advance genotype (G) tested across six environments (E).

The biplot results of the two seasons at three locations showed the consistent expression of high stable grain yield performance of genotype FG12-259; followed by FG12-23, FG12-49, FG14-43, G13-126, G15-11, G14-10 and G16-104 (Fig.2-A). The AMMI analysis found environment at Rice Research Station, Burma, Region # 5, Spring crop, 2018 (E2) and Anna Regina, Region # 2, Autumn crop, 2018 (E4) were observed to be the most representative and ideal test environments (Fig. 1-B&C). The what-won-where biplot pattern suggested the target environment consisted of three mega-environment (Fig.2-D). The three check cultivars GRDB 10 GRDB 12 and GRDB14 also expressed similar higher level of stable grain yields over all test environment (Fig.2-A&D).

Conclusions

Genotype *viz.* FG12-259, FG12-23, FG12-49, FG14-43 and G13-126 expressed higher stable grain yield performance, similar to the 3 check cultivars (GRDB 10,12 and 14). E2 and E4 were identified as the most representative and ideal test environments in this study.

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Productivity and quality of rice varieties of ARRRI breeding

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ABSTRACT

Development, introduction of new rice varieties into production, the development of cultivation technology regimes, the development of an algorithm for their use in certain agro-climatic zones is a prerequisite for obtaining high yields with high grain quality of this valuable agricultural crop. Evaluation for the elements of yield structure and grain quality of new rice varieties of Russian breeding: Patriot, Yubileiny 85, Apollon, Nautilus, Istok, Ametist, Favorit, Prestige, Yakhont and Rapan (st) grown in the Krasnoarmeysky district, Krasnodar region in 2018, 2019 was made. Significant differences were revealed by gradations of factors “variety” - “predecessor”, “variety” - “year”. The predecessors had the greatest influence on yield variability, the worst condition for rice development was the predecessor “rice”. The maximum yield of rice varieties for two years was in the case of alfalfa and soil overturning (the second year after alfalfa), which is probably due to the availability of nitrogen in the soil. The maximum average yield for all variants was noted for the varieties Patriot (9.78 t ha^{-1}), Apollon (9.44 t ha^{-1}), Nautilus (9.24 t ha^{-1}). High milled rice quality characterized short-grain varieties Apollon, Nautilus and a medium-grain variety with a larger caryopsis Ametist.

Key words: rice varieties, yield, sterility, harvest index, paddy rice, head rice, milled rice, whole kernel, broken kernel, chalky kernel

1. Introduction

In Russia, rice is sown in nine regions on an area of 190-200 thousand ha annually. Krasnodar region produces more than 80% of the total rice yield in Russia. Регион характеризуется благоприятными условиями для производства риса и развития отрасли. In recent years, efficiency of agriculture has been increasing, crop rotation is saturated from up to 62.5%, variety change and the introduction of high-yielding varieties tolerant to blast with high grain quality are actively conducted. Continuous variety change is carried out in order to further increase yield and grain quality and leads to the introduction of rice varieties adapted to certain agricultural climatic zones. In recent years, rice varieties with a potential yield of 11-12 t / ha have been developed and approved for use after state variety testing (Kovalev, 2015). Many factors of a natural and anthropogenic nature affect the productivity of cenoses of rice varieties and the grain quality: the production potential of genotypes and their response to agro-climatic conditions of cultivation, resistance to diseases and pests, lodging, etc. Significant reductions in yield and rice quality caused by global warming have been recorded, resulting in severe economic losses. (Peng et,al, 2014.Lanning et al., 2011). Yield losses at high temperature were attributed to high sterility of panicles and a decrease in grain size (Prasad P.V.V., 2006). In All-Russian Rice Research Institute, varieties with increased resistance to blast Patriot, Magnat and others have been developed and introduced. The decisive role of the distribution character formed during the photosynthesis of assimilates in the organs of the plant in the production process in the rice varieties with different yields is shown. So, a significant part of them in varieties of the intensive type (Rapan, Vizit and Gamma, etc.) is used to form shoot grain, including increasing the amount of grain by 1 m^2, while increasing the proportion of grain in the total biomass (harvest index) of sowing. In varieties of the extensive type, most assimilates are assimilated to the formation of massive stems, the flow of plastic substances to panicles decreases and the mass of grain from the plant decreases, the number of grains per 1 m^2, the value of harvest index and yield decreases (Skazhennik M.A. et al., 2017) . The use of nitrogen fertilizers over the past four decades has increased by about 17 times (Ali, M.B. et al., 1999; Rahn C.R. et al., 2009). Nitrogen fertilizers affect the yield of varieties and grain quality: yield increases, the content of amylose and grain size do not change, the content of amylopectin decreases (Wang, J. Et al., 2018).

In recent years, All-Russian Rice Research Institute has developed and introduced high-yielding varieties with increased resistance to blast, lodging, and high grain quality, adapted to the agroclimatic conditions of the rice-growing regions of Russia. Kurazh (approved for use in Russia in 2013), Favorit (2014), Istok (2016), Patriot (2016), Apollon (2017), Nautils (2019), Yubileiny 85 (2019), Yakhont (2019) and other varieties underwent ecological and industrial variety testing to assess the agrobiological potential of genotypes, adaptive capabilities and stability based on yield and grain quality (Ogly et al.). The paper presents the results of a study of the yield structure and grain quality of new varieties of Russian breeding in environmental and industrial variety testing in order to further develop an algorithm for using them in production in certain agroecological cultivation zones under the conditions of relevant agricultural technologies.

2. Material and Methods

Short-grain and medium-grain rice varieties: Patriot, Yubileiny 85, Apollon, Nautilus, Istok, Ametist, Favorit, Yakhont, Rapan (st) and Prestige, which is in the state variety test - were grown in ecological and industrial variety testing in rice farms in Krasnodar region in 2018, 2019 g. These are medium-ripening and medium-late ripening varieties with a vegetation period of up to 125 days, tillering up to 4.0 productive stems per plant, strong straw, resistant to lodging. The height of the plants mostly does not reach 110 cm. Seeds were sown in an ecological variety test, seeding rate (Seed rate (R) 7 million hectares, 20 m^2 in plots, in a production variety test, seed rate 7 million hectares, according to various predecessors: rice, winter wheat, alfalfa, rape. Harvesting was carried out in the phase of full ripeness with a small-sized combine DKC-515. Evaluation was carried out according to the elements of yield structure — yield, mass of one panicle, sterility, harvest index, and traits of grain quality — grain size (mass of 1000 absolutely dry grains, filminess, vitreousity, milling yield (according to ISO 6646: 2011 * "Rice - Determination of the potential milling yield from paddy and from husked rice ", IDT). Moisture content was determined according to ISO 712: 2009 Cereals and cereal products - Determination of moisture content - Reference method.

3. Results and Discussion

3.1 Yield and yield structure

In 2018, by the predecessor of alfalfa, the yield of varieties was distributed as they increased: Yakhont, Favorit, Yubileiny 85, Patriot, Nautilus, Apollon, Yakhont, Rapan. By the predecessor winter wheat: Yubileiny 85, Apollon, Nautilus, Rapan, Yakhont, Prestige, Patriot, Favorit . The yield of rice varieties in 2019 was lower than in 2018. The maximum yield of rice varieties for two years was in the case of alfalfa and soil overturning (the second year after alfalfa), which is probably due to the availability of nitrogen in the soil. The maximum average yield for all variants was noted in the varieties Patriot (9.78 t ha^{-1}), Apollo (9.44 t ha^{-1}), Nautilus (9.24 t ha^{-1}). According to the predecessors of winter wheat, rice, and rape, the yield of varieties was lower. The yield in the rice variant of

Nautilus and Yubileiny 85 sharply decreased, which indicates a lack of available nitrogen in the soil. Given the nature of the reaction, the worst growing conditions were found in the rice variant (table 1). The assessment of yield structure of rice varieties in the production varietal test (2019, table 2).

Table 1. Yield of rice varieties in ecological testing, Krasnoarmeyskiy district, Krasnodar region, yield of 2018, 2019, (t ha^{-1})

Variety	Predecessor					Mean value
	winter wheat	rice	rape	alfalfa	soil overturning	
Patriot	9,67	9,19	9,63	10,25	10,17	9,78
Yubileiny 85	9,00	7,97	8,22	9,21	9,68	8,82
Apollon	9,75	8,50	9,52	9,35	10,06	9,44
Nautilus	9,66	7,94	9,21	9,56	9,83	9,24
Favorit	9,28	8,09	8,73	10,57	9,19	9,17
Prestige	7,70	8,78	8,86	9,96	10,06	9,07
Yakhont	9,35	8,20	8,84	9,94	8,39	8,94
Rapan, st	9,03	8,36	8,52	9,73	9,04	8,94
$LSD_{0,05}$	0,32	0,27	0,15	0,22	0,28	0,39

Table 2. Biometric analysis of rice varieties, production varietal test, Krasnoarmeyskiy district, Krasnodar region, yield of 2019

Variety	Mass of 1 panicle (g)	Sterility, (%)	Harvest index
Patriot	3,40	12,6	0,52
Yubileiny 85	3,81	15,8	0,53
Apollon	3,51	16,3	0,52
Nautilus	3,51	5,9	0,58
Istok	3,00	16,7	0,57
Ametist	2,72	10,9	0,50
Favorit	3,14	17,6	0,54
Prestige	3,06	11,2	0,59
Yakhont	4,54	22,9	0,55
Rapan, st	3,30	16,2	0,57
$LSD_{0,05}$	0,082	1,1	0,01

Varieties Yakhont, Patriot, Yubileiny 85, Apollon and Nautilus were characterized by large mass panicles, respectively 4.54, 3.40, 3.81, 3.51 and 3.51 g. In Ametist, Istok, Favorit and Prestige, panicles are lighter in weight from 2.72 at Ametist to 3.06 g at Prestige. Sterility was higher among Favorit (17.6%), Istok (16.7%), Apollon (16.3%). Sterility in Nautilus (5.9%) and Ametist (10.9%) was rather low. Yakhont, Nautilus and Istok (0.55-0.59) possessed a sufficiently high harvest index. Thus, according to the set of parameters of the yield structure elements, the varieties Nautilus, Apollon, Patriot, Prestige are considered to be promising.

3.2 Grain quality

Grain quality traits of rice varieties were studied for all variants in 2018, 2019. The results (average) are presented in table 3.

Table 3. Indicators of grain quality traits of rice varieties, 2018, 2019

Variety	Mass of 1000 absolutely dry grains (g)	Total milled rice (%)	Head rice content (%)	Vitreousity (%)	Grain length to width ratio
Patriot	26,5	68,6	60,4	94	1,9
Yubileiny 85	24,0	67,8	54,9	95	2,0
Apollon	25,8	69,6	62,7	97	2,1
Nautilus	25,0	69,0	64,5	98	2,1
Istok	25,8	67,8	54,5	96	2,2
Ametist	28,5	67,4	61,0	80	2,3
Favorit	30,0	65,6	51,4	82	2,3
Prestige	29,0	67,2	50,7	90	2,3
Yakhont	28,5	67,4	60,8	91	2,4
Rapan (st)	25,5	68,2	60,8	94	2,0
$LSD_{0,05}$	0,18	0,14	0,21	1,9	-

The short-grain varieties Apollon, Nautilus and medium-grain Ametist were recognized as the best for total milled rice (head rice content - 61.0-64.5%). Varieties Favorit and Prestige were more susceptible to crushing during the production of milled rice, which is typical for varieties with a larger caryopsis.

Conclusions

The results of the studying the elements of yield structure and grain quality of new rice varieties approved for use in Russia are obtained. Significant differences were revealed by gradations of factors “variety” - “predecessor”, “variety” - “year”. The worst conditions for rice development were provided by the predecessor “rice”. The maximum yield of rice varieties for two years was in the case of alfalfa and soil overturning (the second year after alfalfa), which is probably due to the availability of nitrogen in the soil The maximum average yield for all variants was noted for the varieties Patriot (9.78 t ha-1), Apollon (9.44 t ha-1), Nautilus (9.24 t ha-1). High milled rice quality characterized short-grain varieties Apollon, Nautilus and a medium-grain variety with a larger caryopsis Ametist.

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New Clearfield Rice lines – Uruguay Rice Breeden Program.

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ABSTRACT

The INIA Rice Breeding Program located in Treinta y Tres, Uruguay has been working for many years on Clearfield Rice. Recently we start the multiplication of three lines that were obtained using CFX 18 and Puitá INTA CL, as imidazoline source of resistant. The objective of the rice breeding program has been to develop Clearfield cultivar that overcomes some of the limitations of CL 244, CL 212 and Gurí INTA CL (Commercial Clearfield varieties) such as blast resistance, yield potential and rice quality, particularly chalk. One of the new lines CL1202, is *Indica type* with a long cycle, like INIA Merin, resistance to blast and very good milling and cooking quality. CL1202 has smooth leaf with high capacity of tillering and the plant can reach 100 cm but it does not lodge. In 2019 on several yield test CL 1202 perform in terms of yield very similar to INIA MERIN (10.6 ton/ha). On the other hand, CL 1294 and CL1304 are also *Indica type* but with an intermedia to short cycle and shorter plant compare to CL1202. These two lines have been on yield test for 3 year in Paso de la Laguna. Where CL 1294 yield 5% more that Gurí INTA CL, CL1304 yield 2 % less than the check, Gurí INTA CL but booth lines have resistant to blast and good milling quality. On average Gurí INTA CL has 5.3 % of chalk when CL 1294 and 1304 have 2.9 and 2.6 % of chalk respectively. All three liens have been tested for cooking quality and they are comparable to Gurí INTA CL without objection.

Key words: Clearfield, Variety, Rice Breeding

New Clearfield Rice lines – Uruguay Rice Breeden Program

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Introduction

The Clearfield rice area in Uruguay has remained stable in the last three years by 25%. Almost half of the area was planted with the Rice Tec hybrid INOV CL and the other half was planted with Gurí INTA CL and two INIA lines, CL244 and CL212. The INIA Rice Breeding Program located in Treinta y Tres, Uruguay has been working for many years on Clearfield Rice. Recently we started the multiplication of three lines that were obtained using CFX 18 and Puitá INTA CL, as imidazoline source of resistance.

Objective

The objective of the rice breeding program has been to develop Clearfield cultivar that overcomes some of the limitations of CL244, CL 212 and Gurí INTA CL (Commercial Clearfield varieties) such as blast resistance, yield potential and rice quality, particularly chalk.

Material and Methods

- Pedigree selection of crosses made with donors lines in 2009/10.
- At least tow or tree backcrosse made in Paso de la Laguan, Terinta y Tres, with cultivars of excellent cooking quality.
- Best lines were evaluated in different experiment with replication.
    - Two year of evaluation: BCA with two replication and plots of 4.2 m²
    - Two year of evaluation: BCA with three replication and plots of 4.2 m²
    - One year of evaluation in big plots, commercial fields (ongoing)
- Seed increase for small commercial areas of CL1202, CL1294 and CL 1304 (ongoing)

Results

CL1202, is Indica type with a long cycle, like INIA Merin, resistant to blast and very good milling and cooking quality. CL1202 has smooth leaf with high capacity of tillering. Plants can reach 100 cm but they wont lodge. In 2019 on several yield tests, CL 1202 performs in term of yield very similar to INIA Merin (10.6 ton/ha).

Table 1: Yield and milling quality of CL1202 at commercial fields in Big Plots 2018/19

Cultivars	Yield. ton/ha	Milled rice %	Head rice %	Chalk %
El Paso 144	9.97	69.9	66.2	3.7
Merín	10.69	71.8	67.9	2.3
CL1202	10.74	69.7	64.8	2
CV(%)	11.8	1.1	2	29.8
Prob. Locaction	0.06	0.03	0	0.2
Prob. Cultivar	0.25	0	0	0
Prob. LxC	ns	ns	ns	0.15

Conclusions

CL1202, CL1294 and CL1304 are new Celarfield Indica lines with high yield, excellent agronomics trait manly resistant to blast and low chalk. According to our tests the cooking quality is a outstanding point on all lines

On the other hand, CL 1294 and CL1304 are also Indica type but with an intermedia to short cycle and shorter plants, compare to CL1202. These two lines have been on yield test for 3 year in Paso de la Laguna. Where CL 1294 yield 5% more that Gurí INTA CL, CL1304 yield 2 % less than the check, Gurí INTA CL but booth lines have resistant to blast and good milling quality. On average Gurí INTA CL has 5.3 % of chalk when CL 1294 and 1304 have 2.9 and 2.6 % of chalk respectively. All three liens have been tested for cooking quality and they are comparable to Gurí INTA CL without objection.

Table 2: Yield test, Paso de la Laguna (2016/17 – 2018/19)

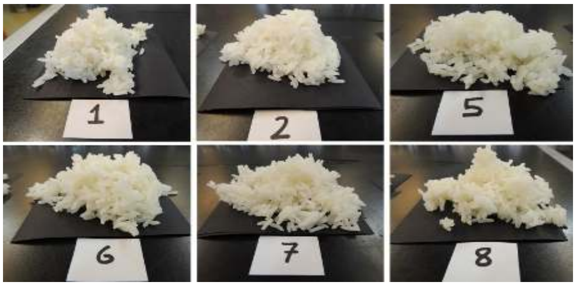
Cultivar	Yield kg/ha	Days to Heading	Height cm	Pyricularia leaf (1)	White rice %	Head rice %	Chalk %
CL 1294	10160	102	88	0	68.7	63.5	2.9
CL 1304	9404	100	90	0	68.4	60.3	2.6
Gurí CL	9615	104	87	4	69.5	62.3	5.3

Table 3: Cooking quality test of new lines

Cultivar	Looseness	Texture	% Amilose*	G.T *
El Paso 144	2.0	4.0	29.5	Low
INIA Olimar	3.0	4.0	31.0	Low
INIA Tacuarí	2.0	2.0	27.3	High
INIA Merín	1.5	3.0	29.8	Low
CL 1202	2.0	3.5	31.0	Low
CL 1294	3.0	4.0	29.6	Low
CL 1304	3.0	4.0	29.7	Low
Gurí INTA CL	2.5	3.0	29.8	Low

Loosenes socre (visual): 1 Completely added, 4 No aggregates.
Texture score on palate: 1 Sticky, 2 Soft and Wet, 3 Soft, 4 Consistent, 5 Hard.

Figure 1: Cooking quality test of new lines



Note: 1 El Paso 144, 2 INIA Olimar, 5 CL1202, 6 CL1294, 7 CL1304, 8 Gurí CL

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Genetics of Grain Arsenic Content in Two Advanced Rice Breeding Populations

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ABSTRACT

Arsenic species have a well documented toxic effect in humans. Growing rice that meets international standards for total (tAS) and inorganic arsenic (iAs) is key for human food innocuity and access of rice production to international markets. An important proportion of the variation in both tAs and iAs in rice grain is due to genetic factors. Breeding for low As content requires assessing the genetic diversity and developing suitable selection strategies for this trait. Standard laboratory methods for quantification of tAs and iAs in rice grain are expensive and low-throughput, thus are not suited for selection in breeding. This work presents the first evaluation of the genetic variability of grain tAs and iAs content in Uruguayan rice germplasm, and a genome-wide association study of grain tAs content to assess the usefulness of marker assisted selection. Two populations (150 indica and 150 tropical japonica) were genotyped-by-sequencing and their grain tAs content measured by Graphite Furnace Atomic Absorption Spectrometry. A subset of 32 genotypes representing the genotypic diversity of both populations was assayed for grain iAs and tAs content with High Pressure Liquid Chromatography-Inductively Coupled Plasma Mass Spectrometry. A significant genotypic effect was found, enabling the selection of advanced lines with low grain tAs and iAs content. For tAs, six QTL were found in the indica population, and other different 8 QTL in the tropical japonica population explaining 48% of the phenotypic variance, respectively. Content of tAs and iAs in the grain were significantly correlated (0.3, $p<0.01$) in the 32 genotypes subset. These results suggest the feasibility of MAS in breeding for low grain As content in Uruguayan rice germplasm.

Key words: association mapping, food innocuity, *Oryza sativa*, arsenic.

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Genetics of Grain Arsenic Content in Two Advanced Rice Breeding Populations

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Introduction

Arsenic species have a well documented toxic effect in humans. Growing rice that meets international standards for total (tAS) and inorganic arsenic (iAs) is key for human food innocuity and access of rice production to international markets. An important proportion of the variation in both tAs and iAs in rice grain is due to genetic factors. Breeding for low As content requires assessing the genetic diversity and developing suitable selection strategies for this trait. There is no previous information on tAs and iAs grain content in INIA's breeding germplasm. Furthermore, standard laboratory methods for quantification of tAs and iAs in rice grain are expensive and time consuming, thus are not suited for selection in breeding. The genetic variability for As content in the breeding germplasm, and the use of new selection strategies such as marked assisted selection (MAS) must be assessed.

Objectives

- Evaluate for the first time the genetic variability of grain tAs and iAs content in Uruguayan rice germplasm.
- Explore the correlation between tAs and iAs in breeding trials.
- Dissect the genetic architecture of grain tAs in INIA's breeding populations
- Assess the usefulness of MAS for grain tAs.

Material and Methods

Two mapping populations (129 indica and 201 tropical japonica) were phenotyped in a field trial with an augmented randomized complete block design in 2018 and their grain tAs content was measured by graphite furnace atomic absorption spectrometry (GF-AAS) and inductively coupled plasma mass spectrometry (ICP-MS) at Laboratorio Tecnológico del Uruguay (LATU) and Trace Element Speciation Laboratory (TESLA, Aberdeen University, UK). A subset of 32 genotypes (17 indica and 15 tropical japonica) representing the genotypic diversity of both populations was grown in a field trial with a randomized complete block design with three replicates in 2019 and assayed for grain iAs and tAs content with HPLC-ICP-MS at LATU.

A genome-wide association study (GWAS) between single nucleotide polymorphism genotyped by sequencing (GBS-SNP, 49K for indica and 27K for tropical japonica) and tAs in the mapping populations was performed with a mixed model accounting for population structure implemented in the R package rrBLUP. Quantitative trait loci (QTL) for tAs were defined as >2 SNPs with significant association ($p<0.0001$) in the same LD block ($r^2>0.5$). The significance of all SNPs with the highest $-\log_{10}(p)$ of each QTL was jointly tested in a multi-locus model, removing non-significant SNP with a backwards procedure ($p<0.05$). Pearson correlation between iAs and tAs was estimated for the 32 lines subset.

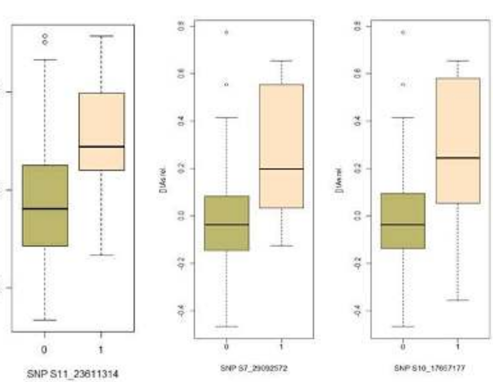

Fig 3. Allelic substitution effects for SNP representing the QTL that were significant in the multi-locus model.

Results

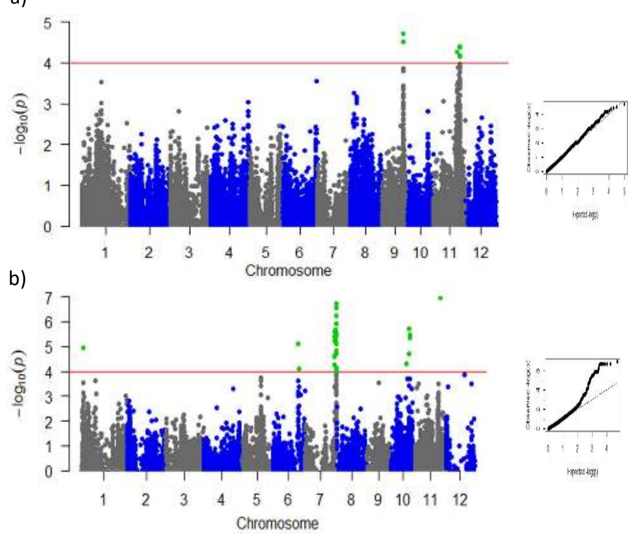

Fig 1. Manhattan and QQ plots with GWAS results for grain tAs in a) indica and b) tropical japonica populations. Significant associations are shown in green.

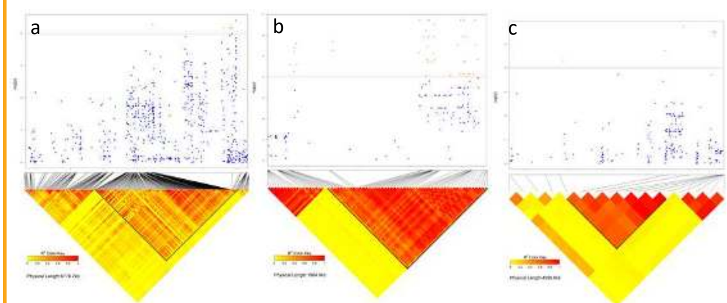

Fig 2. Zoomed-in regions of QTL for grain tAs that were significant in the multi-locus model. a) chromosome 11 (indica), b) chromosome 7 (tropical japonica), c) chromosome 10 (tropical japonica). The lower panel shows LD patterns with linked SNP with LD blocks in red.

The GWAS showed different architectures for indica and tropical japonica. Two QTL in chromosomes 9 and 11 were discovered in the indica population. Only the QTL in chromosome 11 was significant in the multi-locus model, with SNP S11_23611314 explaining 20% of the phenotypic variance. For tropical japonica, QTL in chromosomes 7 and 10 were identified, together explaining 20% of the phenotypic variance in the multi-locus model. The correlation between iAs and tAs in the 15 tropical japonica lines was 0.43, and no significant correlation between iAs and tAs was found for the 17 indica lines.

Conclusions

The genetic variance for tAs and iAs in INIA's advanced germplasm is adequate for breeding new cultivars with improved innocuity. tAs may be used as a proxy for iAs in tropical japonica, but more studies are required for indica. Our preliminary results with one year of field phenotyping suggest a low number of loci determining tAs, and thus a probable usefulness of MAS in both populations. However, more trials and years are required to rule out the magnitude of genotype and QTL by environment interactions.

Comparison of Conventional and GBLUP Genome-wide association mapping of cold tolerance in advanced rice breeding populations

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ABSTRACT

Rice cold tolerance at seedling and reproductive stage is crucial for high yield stability in subtropical and temperate rice growing areas. Field phenotyping for this traits is often confounded by phenology, seeding date, and weather conditions. Therefore, marker assisted or genomic selection could be useful depending on how complex is the trait's genetic architecture in the breeding population. Genome-wide association studies (GWAS) enable to dissect the genetic architecture in breeding populations. The conventional GWAS method commonly used in plant breeding (CGWAS) tests the association between the phenotype and each SNP separately, which has some drawbacks such as the need of multiple-testing correction and low power due to correlation between markers. Fitting a mixed model to get the best linear unbiased prediction of all the SNP simultaneously overrides these limitations. One approach is to use the marker-based G matrix of realized genotypic relationships (GBLUP). The GBLUP strategy is usually employed for GWAS in animal breeding but has been scarcely explored in plants. This work compares GBLUP with CGWAS for cold tolerance at seedling stage in two rice breeding populations (306 indica and 302 tropical japonica inbred lines, genotyped with ~50K and ~30K SNP, respectively) adapted to the subtropical Uruguayan rice growing area. The correlation between the p-values of CGWAS and GBLUP was 0.988 and 0.925 for the indica and tropical japonica population respectively. A total of 14 QTL were found in the indica population, and 18 in the tropical japonica population. There was 1 QTL in indica and 2 in tropical japonica that were detected with CGWAS but were not significant with GBLUP. Conversely, there were 3 QTL for indica and 8 for tropical japonica that were detected only with GBLUP. This suggest that GBLUP better reveals the full genetic complexity of the cold tolerance in both breeding populations.

Key words: Genomic selection, mixed models, *Oryza sativa*, cold tolerance at seedling stage.

Comparison of Conventional and GBLUP Genome-Wide Association mapping of cold tolerance in advanced rice breeding populations

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Introduction

Rice cold tolerance at seedling and reproductive stage is crucial for high yield stability in subtropical and temperate rice growing areas. Field phenotyping for this traits is often confounded by phenology, seeding date, and weather conditions. Therefore, marker assisted or genomic selection could be useful depending on how complex the trait's genetic architecture in the breeding population is.

Genome-Wide Association Studies (GWAS) enable to dissect the genetic architecture in breeding populations. The Conventional GWAS method commonly used in plant breeding (CGWAS) tests the association between the phenotype and each Single Nucleotide Polymorphism (SNP) separately, which has some drawbacks such as the need of multiple-testing correction and low power due to correlation between markers. Fitting a mixed model to get the Best Linear Unbiased Prediction (BLUP) of all the SNP simultaneously overrides these limitations. One approach is to use the marker-based G matrix of realized genotypic relationships (GBLUP) and this strategy has scarcely been explored in plants.

Objectives

- Detect Quantitative Trait Loci (QTL) associated with cold tolerance at seedling stage.
- Compare GBLUP and CGWAS methodologies.

Material and Methods

Phenotypic information: With a complete random blocks design with three blocks, 306 ssp. indica lines and 302 ssp. tropical japonica lines were evaluated. At 21 days post seedling, lines undergone a 5 °C ± 0,5 during 32 h treatment. Seven days after the treatment, damage was registered, relative to cold sensitive and tolerant witnesses.

Genotypic information: 50K SNP of the 306 ssp. indica lines and 29K SNP of the 302 ssp. tropical japonica lines, obtained by Genotyping By Sequencing.

CGWAS was implemented using the following model:

vector of fixed effects

random genotypic effects with $u \sim N(0, Gu2)$ where G is the realized genotypic relationship matrix

vector of adjusted phenotypic means for each line $\longleftarrow$

$$y = Xb + Zu + e$$

$\longrightarrow$ residual effects vector with $e \sim N(0, I_e^2 2)$

incidence matrices that relate y with b and u

In CGWAS, fixed effects are the general mean and each SNP separately while in GBLUP fixed effects are only the general mean. In GBLUP, SNPs effects and the significance of associations was be derived from genomic breeding values (u), following the methodology used by Gualdrón Duarte et al. (2014) and the calculations proposed by Aguilar et al. (2019) to obtain p-values.

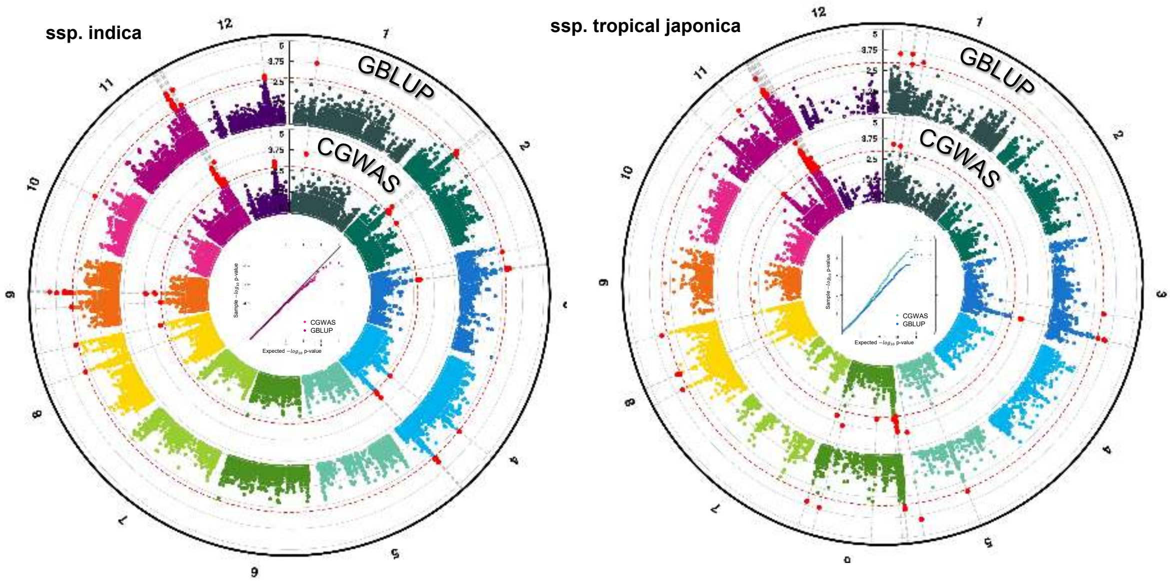

Figure 1. Ciruclar Manhattan Plots and QQ-plots of GWAS for each ssp. and methodology: indica (left) and tropical japonica (right), Manhattan Plot of CGWAS (inner circle), Manhattan Plot of GBLUP (outer circles), QQ-plots (inside the circles).

Results

The correlation between the p-values of CGWAS and GBLUP was 0.988 and 0.925 for the Indica and tropical japonica population respectively. A total of 14 QTL were found in the indica population, and 18 in the tropical japonica population. There was 1 QTL in indica and 2 in tropical japonica that were detected with CGWAS but were not significant with GBLUP. Conversely, there were 3 QTL for indica and 8 for tropical japonica that were detected only with GBLUP.

Conclusions

Both methodologies allowed the identification of novel QTL for cold tolerance in seedling stage but GBLUP better revealed the full genetic complexity of the cold tolerance in both breeding populations.

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Consolidating INIA's Rice Breeding Program Database, Phase I: Historical Indica Trials

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ABSTRACT

INIA's Rice Breeding Program (IRBP) is the major rice breeding program in Uruguay. To deliver improved cultivars, the performance of thousands of experimental lines is assessed in field and laboratory trials. The joint analysis of all the experimental data, combining multiple years, locations and trials, allows better estimations of the genetic value of the breeding lines and thus optimizes the efficiency of the breeding program. Records of historic field and laboratory trials of the IRBP are fragmented in a multiplicity of media and formats that prevent their joint analysis. This work describes the integration of a database corresponding to the Indica subtype materials, which constitutes approximately half of the IRBP germplasm. It comprises data from field and lab trials across 14 years (2006 to 2019) and three locations. The strategy used was: 1) Implementation of uniform templates with standardized field names. 2) Manual review and quality control of data (variable identification and assignation to a standardized field, check units of measurement, check cell format, identification of missing data, and standardized annotation of qualitative observations). 3) Reading of the formatted spreadsheets of each trial with the R software, consolidating all trials in a single data frame with all the Indica IRBP data. 4) Standardization of field values (missing data and standardized levels for categorical variables). 5) Trial-wise quality control with statistical criteria (distribution of variables, trial heritability, spatial distribution of residuals). A database with around 26,000 records was obtained, comprising about 200 trials. Consolidated data will be crucial for implementing multiple-environment analysis that will enhance selection accuracy and improve genetic gain in the IRBP.

Consolidating INIA's Rice Breeding Program Database, Phase I: Historical Indica Trials

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Introduction

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The joint analysis of all the experimental data, combining multiple years, locations and trials, allows better estimations of the genetic value of the breeding lines and thus optimizes the efficiency of the breeding program. Records of historic field and laboratory trials of the IRBP are fragmented in a multiplicity of media and formats that prevent their joint analysis.

This work describes the integration of a database corresponding to the Indica type materials, which constitutes approximately half of the IRBP germplasm. It comprises data from field and lab trials across 14 years (2006 to 2019) and three locations.

Objective

Present the methodology used to consolidate IRBP's database, as well as preliminary analysis' results.

Material and Methods

The strategy used was:

1)Implementation of uniform templates with standardized field names.

2) Manual review and quality control of data (variable identification and assignation to a standardized field, check units of measurement, check cell format, identification of missing data, and standardized annotation of qualitative observations).

3) Reading of the formatted spreadsheets of each trial with the R software, consolidating all trials in a single data frame with all the Indica IRBP data.

4) Standardization of field values (missing data and standardized levels for categorical variables).

5) Trial-wise quality control with statistical criteria: distribution of variables, trial heritability, best linear unbiased predictions (BLUPs) of genotypic breeding values. Trial heritability was estimated following Falconer and Mackay (1996) with the equation:

$$h^2 = \frac{V_G}{V_G + {V_R}/{rep}}$$

V_G: genetic variance, V_R: residual variance, rep: number od repetitions.

BLUPs were obtained fitting the linear mixed model for each trial:

$$y_{ij} = G_i + block_j + e_{ij}$$

Y_{ij}: observed phenotypic value of the i^{th} genotype in the j^{th} block, G_i: random genotypic effect of the i^{th} genotype, $block_j$: fixed effect of the j^{th} block, e_{ij}: residual random effect of the i^{th} genotype in the j^{th} block.

Results

A database with more than 27,416 records was obtained, comprising 270 trials in 14 years, with 5,126 lines evaluated. A total of 35 variables related to phenology, yield and grain quality, disease incidence and pedigree were considered.

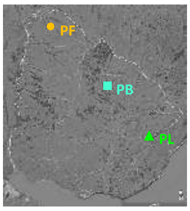

Figure 1. Locations of IRBP Experimental fields: *Paso Farías* (PF, advanced and final evaluations); *Pueblo del Barro* (PB, advanced and final evaluations); *Paso de la Laguna* (PL, all stages).

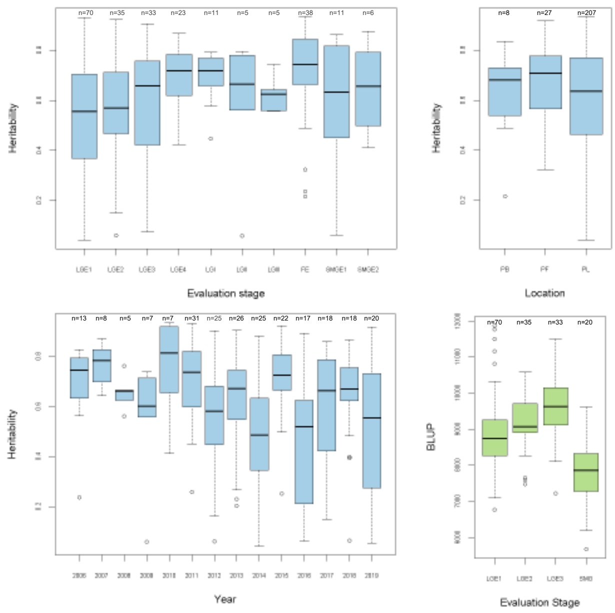

Figure 2. (a) Heritability by evaluation stage, (b) Heritability by location, (c) Heritability by year, (d) Trial-wise BLUPs by evaluation stage.
LGE1 to LGE4: Long grain (indica type) yield evaluations years 1st to 4th; FE: Final evaluation (indica type); SMGE1/E2: short medium grain (temperate japonica type) yield evaluation years 1st and 2nd; PL: Experimental Unit *Paso de la Laguna*; PB: Experimental field *Pueblo del Barro*; PF: Experimental field *Paso Farías.*

Conclusions and Perspectives

The trial-wise genetic parameters estimated in this work will be used for a quality control of trial data, to select good quality trials for the joint analysis. The consolidated data will be crucial for implementing joint modeling for multiple-environment analysis that will enhance selection accuracy and improve genetic gain in the IRBP.

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Boosting INIA's Rice Breeding Program with Molecular and Quantitative Genetics Approaches

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ABSTRACT

As a major rice exporter, Uruguay must maximize its competitivity with higher yield, quality and innocuity, and lower inputs, in an increasingly instable environment. To timely meet these needs, INIA's public rice breeding program (IRBP) is optimizing its cultivar development pipeline by incorporating molecular and quantitative genetics approaches that will enable to increase the selection accuracy and intensity, and to shorten the breeding cycle. Different strategies are applied depending on the complexity of the target trait in the breeding germplasm: 1) molecular assisted selection (MAS) for screening and introgression of valuable alleles for oligogenic traits, for increasing selection intensity and reducing population size for field trials; 2) genome-wide association studies (GWAS) for traits with unknow genetic architecture in our germplasm; and 3) mixed models integrating pedigree, genomic, and weather data for prediction complex traits under favorable and unfavorable environments for increasing selection accuracy. For MAS, SNP markers have been validated and applied for blast resistance, herbicide tolerance, amylose content and fragrance. GWAS were performed in indica and tropical japonica advanced breeding germplasm for arsenic grain content, tolerance to low temperature at vegetative and reproductive stages, and quantitative blast resistance. Several new and known QTL were discovered in the IRBP germplasm, and the usefulness of MAS for these traits was assessed. Finally, prediction of breeding value for yield is being implemented combining historic phenotypic and pedigree records with environmental data. First analyses of multi-year and multi-location analyses are showing promising results for increasing selection accuracy and characterizing genotype by environment interactions. Combined, these molecular and quantitative approaches are contributing to optimize the IRBP, and will accelerate the delivery of best cultivars for Uruguayan rice farmers.

Key words: breeding, MAS, GWAS, genomic selection.

Contribution of FLAR breeding program to increase cold tolerance and shortening growth cycle in Chilean rice germplasm

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ABSTRACT

Low temperatures during the cropping season are the main constrain in Chilean rice production. However, 25,000 to 27,000 hectares are planted around San Carlos (36.41°S) and Linares (35.84°S) region in the central south valleys. Growth cycles (GC) are very long in the currently cultivated varieties. Therefore, there is high risk of coincidence of heading time with low temperatures affecting fertility and yield. In addition, long GC varieties require more water, which is a limited resource in that region. The main objectives of the FLAR-INIA collaboration is to develop shorter GC rice germplasm, with cold tolerance, and other desirable agronomic and grain quality traits. Shorter GC germplasm from Europe has been introduced in Chile, but milling quality does not meet local demand of the industry. Progenies from crosses between local varieties with the Hungarian variety Sandora were introduced from Colombia. Individuals were selected in F2 populations in Chile and advanced in Colombia. Evaluations in yield plots have showed that materials derived from these crosses have potential to become new varieties. Line FLQuila-24 had shorter cycle than Zafiro in regional plots in Linares, Parral and San Carlos with ten, three and six days less, respectively. No significant differences in yield were observed between FLQuila-24 and Zafiro. Sterility in the southernmost location of rice production in the world, San Carlos, was lower in FLQuila-24 (12.3%) than in Zafiro (18.4%). Sterility is measured as cold tolerance indicator. Other lines in yield plots and observational trials presented shorter GC and lower sterility, but with lower yield. Advances have been made in reducing GC and increasing cold tolerance using Japonica germplasm in the FLAR-INIA partnership in ten years of collaboration. New germplasm is being generated to increase grain weight and quality to accomplish new requirements in industry.

Key words: Sterility, Grain quality, Southernmost rice.

Cooking quality in Latin American temperate rice determined by grain viscosity profile

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ABSTRACT

Cooking quality is a very important trait for rice in the temperate countries in Latin America. Historically, percentage of amylose content has been an indicator for selection of germplasm in local breeding programs. However, amylose content is not sufficient to determine all the cooking and sensorial components of quality in order to differentiate different markets and local preferences and increase accuracy in selection. The Latin American Fund for Irrigated Rice (FLAR) is interested in determine the desired quality profile of rice in the entire region. Samples of polished rice were obtained from Argentina, Brasil, Chile and Uruguay. These samples were divided in commercial rice acquired in supermarkets, polished grain of the most planted varieties in the region and from advanced breeding lines from the FLAR and local breeding programs. Grain appearance, size, gelatinization temperature, amylose content and rheological properties as breakdown and setback were evaluated using three repetitions by sample. Data was analyzed using multiple correspondence analysis for descriptive categories. Results groups the samples in four quality clusters. Long B grains compose first cluster, this rice remains partially separate and consistent after cooking. Cluster 2 is mainly composed by Chilean samples, characterized by lower amylose temperate japonica rice, long A grains, and grains remains sticky and soft after cooking. Long A and long B rice, but with grains that remains partially separated and soft after cooking compose cluster 3, in this cluster is included mainly Chilean samples and materials from others countries focused in specific markets. Cluster 4 is composed by long B rice that remains totally separated and consistent after cooking, some of the samples in this group are considered premium quality. This information is important to determine the grain quality profile and direct the breeding programs to the consumers and markets preferences.

Key words: Quality profile, breakdown, setback.

Identifying loci and developing reliable markers for low temperature tolerance at the young microspore stage.

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ABSTRACT

In temperate Australia, and other temperate regions globally, yield stability in rice can be improved by improving low temperature tolerance at the young microspore stage (YMS), where minimum temperatures as high as 18-19°C can result in reduced spikelet fertility in the most susceptible genotypes. The lack of low-cost repeatable phenotyping method has led to the desire for a reliable molecular marker for marker-assisted selection. Two populations, which utilise Lijiangheigu and Norin PL8 (from China and Japan, respectively) as low-temperature tolerant donors, developed by the Australian breeding program were phenotyped for low-temperature tolerance (15/21°C) for 14 days at the YMS. These populations were subsequently genotyped using genotyping by sequencing technology, DArTseq.

Screening of the two populations identified lines that had comparable performance to the tolerant parents. Association analysis identified seven and five loci that had a significant association with spikelet fertility in the Kyeema//Kyeema/Norin PL8 (KKN) and M205/3/M205//Millin/Lijiangheigu (2MML) population respectively. In the KKN population, the seven loci accounted for 42% of the additive genetic variance. The two largest effect loci from the 2MML population was estimated to double spikelet fertility when homozygous for the tolerant allele.

Low temperature tolerant progeny from the two crosses have been crossed to multiple backgrounds to evaluate the loci utilitarian value to the breeding program. Furthermore, existing KASP assays in the loci region are being explored on whether they could be used for selection. If the value of the loci is demonstrated across multiple background, it is expected that a reliable maker for cold tolerance will be available to the breeding program within the next year.

Key words: young microspore, low temperatures, molecular breeding.

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Identifying loci and developing reliable markers for low temperature tolerance at the young microspore stage.

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Introduction

In temperate Australia, yield stability in rice can be improved significantly by increasing low temperature tolerance at the young microspore stage (YMS; Figure 1). The lack of a low-cost repeatable phenotyping method has led to the need for development of reliable molecular markers for marker-assisted selection.

Figure 1: An example of high (bottom) and low (top) sterility genotypes after cold exposure (15/21°C) at YMS for 14 days.

Objective

- Identify stable QTL associated with low temperature tolerance at YMS.
- Develop reliable markers for integration into the breeding program.

Material and Methods

- Low temperature tolerant donors, Lijiangheigu (China) and Norin-PL8 (Japan) entered crossing programs with elite material to rapidly introgress tolerance.
- Kyeema//Kyeema/Norin-PL8 (KKN; 117 lines) and M205/3/M205//Millin/Lijiangheigu (2MML; 259 lines) were developed.
- Genotyped by DArTseq™ which resulted in 8765 and 2309 single nucleotide polymorphisms in the KKN and 2MML populations respectively after filtering.
- Phenotyped in controlled temperature conditions using the two set screening method described in Mitchell et al. (2016). The KKN and 2MML received 15/21°C and 14.2/19.0°C respectively for 14 days during the YMS.
- Association analysis was adopted for both populations. The most appropriate model to fit the data was adopted. Significant associations were declared at a probability 10^{-3}.

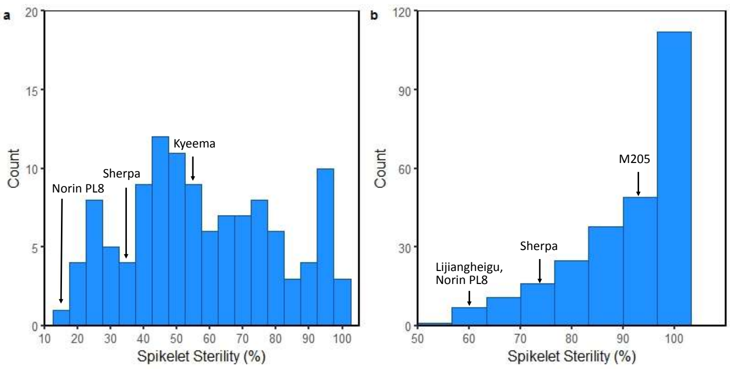

Figure 1: Best linear unbiased predictors for spikelet sterility of the KKN (a) and 2MML (b) populations after cold exposure at YMS for 14 days.

Results

Both populations demonstrated significant genetic variation for spikelet sterility (Figure 2).

- The narrower range in 2MML reflects the lower phenotyping temperatures compared to the KKN.

Seven putative loci were identified in the KKN on chromosomes 1, 2, 3, 5, 7, 10, and 11.

- All together, the loci accounted for 42% of the additive genetic variation and decreased sterility by 8% per tolerant allele (Figure 3a).

Five putative loci were identified in the 2MML on chromosome 1, 6, 10, 11 and 12 (Figure 3b).

- QTL on chromosome 10 and 12 were donated from cold donor, Lijiangheigu, estimated to halve sterility when used in combination.
  - Only 1 marker identified on chromosome 12, potential to be a false positive.

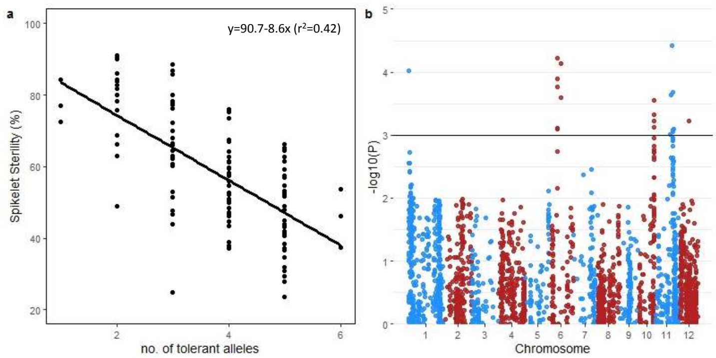

Figure 2: The relationship between spikelet sterility in the KKN population exposed to low temperature at YMS and the number of tolerant alleles (a). Marker associations with spikelet sterility in the 2MML population (b).

Moving Forward

- Cold tolerant individuals from both populations have been crossed with multiple elite backgrounds for validation of the identified QTL and to evaluate their value to the breeding program.
  - Screen of KKN derived crosses is currently underway.
- On validation of a QTL value to the breeding program, we will explore if existing KASP™ assay can be exploited to use as a reliable marker for the selection of low temperature tolerance at the YMS (i.e. McCouch et al. 2010). Otherwise, custom-designed assays will be designed and tested.

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Detecting Acetyl-Coenzyme A Carboxylase Resistance Gene in Rice

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ABSTRACT

The aryloxyphenoxypropionate herbicides (APPs) are graminicides with excellent control of many grass weeds species, including weedy rice (*Oryza sativa* L.). These herbicides block the fatty acid biosynthesis by inhibiting the enzyme acetyl-CoA carboxylase (ACCase), resulting in the death of susceptible plants. The induced mutation with gamma rays to rice seeds resulted in lines resistant to APPs herbicides (Andrade et al., 2018). Plant dose–response assays confirmed the resistance to the APPS herbicides quizalofop-p-ethyl and haloxyfop-p-methyl (Oliveira Neto et al., 2017). The herbicide resistance in rice is conferred by a single point mutation with an amino acid substitution of the carboxyl transferase domain of the ACCase gene. A method based upon allele-specific PCR was developed to detect the SNP G2027T that causes a tryptophan–cysteine substitution in the gene encoding chloroplastic ACCase in rice. The protocol was tested in 453 rice samples from a segregant population for validation of the assay. This technique can be exploited to monitor resistant lines in rice breeding programs to detect homozygous or heterozygous resistant or usceptible plants. The presence of resistant ACCase allele(s) can be detected fastly and at low cost and can be used in any molecular biology laboratory with minimal equipments.

Key words: ACCase inhibitors, herbicide resistance, *Oryza sativa* L.

THE TRENDS AND RESULTS OF RICE BREEDING IN THE RUSSIAN FEDERATION

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ABSTRACT

Rice (*Oryza sativa* L.) is cultivated in the Russian Federation on the northern border of the crop dissipating area in the European part of the country and in the Far East. The main rice sown areas and the leading rice breeding center is in the Krasnodar Territory where rice yield in 2019 reached 7.55 t/ha. The rice varieties bred in the Krasnodar Territory have been successfully cultivated not only in all rice growing areas of Russia, but also in Kazakhstan. Russian breeders are creating rice varieties in various directions – for cold resistance, salt tolerance, high yield and grain quality. All varieties should have increased resistance to diseases and pests, as well as a growing season from 100 to 125 days. In recent years, due to climatic change, another direction of selection for stress resistance has appeared: the creation of rice varieties that are tolerant of air drought. Such varieties possess a modified type of leaf curling when air temperatures exceed 28°C and accompanied by dry wind.

When creating new varieties, the highly effective breeding technology developed by the All-Russian Research Institute of Rice (ARRRI) is used based on intraspecific hybridization and marker selection. The use of biotechnology has allowed the creation of several varieties of rice with genes for resistance to blast, the most harmful rice disease in Russia.

The complexes consisting of rice varieties of different ripeness groups are recommended for farms, rice commercial producers. Much attention is paid to timely varietal change in all rice-growing regions.

Key words: Rice, selection, variety, yield, blast

1. Introduction

Rice is a tropical crop. However, due to its high adaptive ability, rice occupies a wide area over the globe. This is facilitated by the creation of a huge number of heterogeneous varieties by breeding centers of various countries. In the Russian Federation, rice is cultivated on the northern border of the crop dissipating area.

Rice breeding in the RF is carried out in three zones: in the Far East in Primorye, the Rostov Region and the Krasnodar Territory. By 2019, only 68 rice varieties were included into the RF State Register of varieties approved for commercial production, of which 15 over the past three years. All of them were bred by the scientists of the Russian Federation [3].

The varieties with a short growing season are created in Primorye adapted to the local wet and cool weather conditions.

In the Rostov Region, breeding is aimed at obtaining early ripening, salt-resistant rice varieties able to withstand the local arid climate.

In the Krasnodar Territory, where about 80% of Russian rice is grown, the All-Russian Rice Research Institute (ARRRI) has been working on breeding rice since 1931. Here, diverse rice varieties have been created that are cultivated locally, in the Astrakhan and Rostov regions, the republics of

Adygea, Dagestan, Kalmykia and Chechnya. In Russia as a whole, the ARRRI rice varieties occupy 83% of rice sowing areas.

Russian rice varieties bred in the Krasnodar Territory are very popular in Kazakhstan. Here the varieties Lider and Yantar occupy more than 70% of the rice sowing areas [5].

Scientific support of rice production in Russia is a priority and breeders, specialists of Biotechnology and plant protection specialists take an active part in resolving the issues. Rice varieties created for various climatic zones of the country considering stress factors, underlie the innovative activities of the scientists.

The purpose of this study is to analyze the breeding achievements of the Russian breeders and identify new promising areas in the development of rice breeding in Russia.

2. Material and Methods

The ARRRI has developed a highly effective breeding technology that allows the scientists to obtain varieties meeting production requirements. The main element of this technology is the source material with predetermined parameters, intraspecific hybridization, backcrosses and individual selection. The use of artificial climate chambers allows hybridization to be carried out year-round with the level of hybrid kernels formation up to 85% and higher.

To create varieties resistant to blast, marker selection and PCR analysis were used. We also applied microsatellite and intragenic markers using specific primers [2].

3. Results and Discussion

In 2019, in the Krasnodar Territory, rice productivity reached 7.55 t/ha. It was the first case of such a high rice yield obtained in the region. This yield was due to the new varieties, a high level of agrotechnology, as well as the use of “Torum 740” rotary harvesters.

The rice varieties created at the All-Russian Research Institute of Rice belong to different ripeness groups: early ripening with a vegetation period of 100 - 110 days, mid-ripening – 111 - 120 days and mid-late ripening – 121 - 125 days.

The climatic conditions of the Russian Federation allow the cultivation of rice varieties with a growing season of not more than 125 days. This is confirmed by the variety Krasnodarsky 424 which has this duration of the growing season and it has been commercially cultivated for more than 50 years. Rice varieties with a longer growing season in the years with early and cold autumn do not ripen in Russia. Therefore, all attempts to bring here and cultivate rice varieties from the southern regions (Turkey, France, Italy) fail during years with cold autumn. In the rice growing regions of the RF there are 3 to 4 years with insufficient heat during the rice growing season out of each 10 years. Therefore, the selection of rice varieties, adapted to local conditions, is of importance.

Yield and grain quality are the main indicators characterizing the value of rice varieties for commercial production. At the same time, the plants should be resistant to logging and shedding. The grain should be easy to grind and be resistant to crushing during machine harvesting. Rice productivity is limited by such negative factors as diseases, mainly blast disease, and such pests as cereal aphids as well as soil salinization.

The yield of rice varieties is determined by the genotype, environmental conditions and the level of the rice growing agrotechnology.

The scientists of the ARRRI provide varietal complexes for each farm using the bred varieties and based on the farm soils and economic potential. Different types of varieties are recommended for such complexes: one early ripening, 2 to 3 mid-ripening varieties, and 1 to 2 mid-late ripening varieties.

For a long time, the created precocious varieties (Sprint, Novator, Serpantin, Fontan) were little used by farmers. The main reason for this was their lower yield than that of the mid-ripening varieties and, most importantly, poor resistance to blast, especially when combined with high rates of nitrogen fertilizers. In 2019, an early ripening rice variety Azovsky was included into the RF State Register of varieties. The environmental test of 2017 of this variety showed the yield of 9.76 t/ha was received within 103 days of vegetation with perennial grasses as the predecessor. This yield equals that of the mid-ripening varieties. At that the plants of Azovsky were not affected by blast. In 2019, during a production farm tests Azovsky resulted in 10.5 t/ha with a vegetation period of 107 days.

Yields of 10-11 t/ha in the commercial production of the Krasnodar Territory are formed by mid-ripening varieties Istok, Kumir, Polevik, Rapan, as well as mid-late ripening varieties Apollon, Olympus, and others. The yields of these varieties indicate that the issue of increasing rice yield in the RF by breeding is being solved quite successfully. It remains to raise the level of agrotechnology for growing these varieties in order to regularly realize their potential under commercial production.

An important reserve for increasing the productivity of rice varieties is to increase resistance to stress conditions. The potentialities of the above varieties are manifested in fields where there is no loss due to disease. In 2013, when the epiphytotic development of blast was observed on susceptible varieties, rice harvest in the Krasnodar Territory dropped by 20%, despite the fungicide application. Therefore, breeding for resistance to blast is a priority for the Russian breeders [4]. In solving this problem, biotechnologists of the ARRRI take an active part. The use of marker selection allowed us to create several rice varieties with one and two genes for resistance to blast: Alliance, Lenaris, Capitan, Voskhod, Utyos, as well as with three genes (rice variety Piruet) and with five resistance genes (Pentagen) [1].

A serious stress factor for rice in the RF is soil salinization. High soil salinity is maintained by groundwater, the mineralization of which reaches 5.0 g/l or higher. The saline soils of rice growing systems in the Krasnodar Territory occupy 20% of the rice sowing areas, in the Rostov Region - 50%, and in the Astrakhan Region - over 50%. Therefore, the creation of rice varieties with increased salt tolerance is the task number one.

The collection of the ARRRI has accumulated a significant number of samples with a complex of economically valuable traits. Among them, a special group of rice samples and forms with increased salt tolerance (7 points). Among them, the Italian variety *Balilla grana grosso,* a universal donor of a short stem, resistance to lodging and salt tolerance. Several Russian varieties with increased salt tolerance (Spalchik, Zhemchuzhny, Kulon, Primorets, Kurchanka, etc.) were produced using *B. grana grosso* as a source and are now widely cultivated.

A highly productive salt tolerant variety Sonata has been also created with the participation of the salt tolerance donor *Pokkali*; it has been included in the RF State Register. The introduction of such varieties is the most cost-effective direction of agricultural use of saline lands.

In recent years, air drought became an additional negative factor for rice growing in the Krasnodar Territory. It is observed when the temperature reaches 33 - 35°C accompanied by dry winds. In this case, air humidity goes below 30%.

During air drought rice plants do not have enough time to pump water for cooling and gradually lose turgor thus it negatively affects all physiological processes. If drought is observed at the phase of panicle heading - flowering and the initial period of grain filling, the number of sterile spikelets in rice panicles sharply increases. Air drought during the milky – wax stage leads to the formation of not filled, hollow rice grains.

Observations of rice varieties showed that they suffer from dry winds to varying degrees. For example, the variety Krasnodarsky 424 is practically not damaged by drought, because it has narrow leaves, which become grooved when air dryness increases. The short-stemmed variety Sonnet with wide leaves and an erectoid flag leaf was severely damaged in 2017 by the dry winds during the grain filling period. The variety formed a hollow grain and significantly reduced the yield compared to the previous year. The other varieties with large broad leaves were damaged in the same manner.

The variety Avstral with leaves curling at the temperatures above 28°C was bred as a result of many years of selection, in 2013 it was included in the RF State Register. At high air temperatures the evaporation area of the curled leaves decreases, and the rice plants spend less energy on cooling thus preventing damaging effects of the dry wind. When creating the variety Avstral, the AV-1 variety from Australia served as a donor of the “leaf curling” trait. Using Avstral in a series of intervarietal crossings, a new source material was obtained at the IRRRI for breeding the next generation of highly productive rice varieties with the curling leaf trait that are resistant to air drought.

As a result of many years of selection work and the introduction of new rice varieties, Russian producers are fully provided with domestic varieties. In addition, these varieties undergo environmental tests in different countries of the world.

Conclusions

Diverse breeding programs are carried out in the Russian Federation to ensure the production of modern rice varieties adapted to local conditions. They belong to different groups of ripening and are recommended for use in production as part of varietal rotations. Under the conditions of the Krasnodar Territory, early ripening varieties can form a yield of 7 - 8 t/ha, mid-ripening – 9 - 10 t/ha, mid-late ripening – 10 - 12 t/ha.

The main abiotic stressors for rice in Russia are high soil salinity and air drought. The introduction of salt tolerant rice varieties created at the ARRRI allows the efficient use of saline lands. A new direction in rice breeding is the creation of source material resistant to air drought, with leaves curling during the dry season.

The main biotic stress factor is blast. Selection for resistance to this disease is carried out both by traditional methods and using marker selection. As a result of the research the varieties with both field and race specific resistance to the disease have been created. All these rice varieties have been handed over to the State Variety and Production Testing in the conditions of the Krasnodar Territory and the Rostov Region.

The analysis of the breeding achievements of the Russian scientists in the field of rice production allows optimization of the work of the breeding centers and identify priority areas of research.

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Rice Ecophysiology: Climatic Variables and Yield at Uruguay

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Keywords: *elite germplasm, Indica, Tropical Japonica*.

1. Introduction

In the last 20 years the national rice yield has increased at a rate of approx. 150 kg/ha/year, explained by the adoption of high yielding cultivars, improved cultural practices and favorable environmental conditions; average national yields in Uruguay at the last six rice seasons was in the range 8.1-8.6 t/ha (Carracelas et al. 2017). In turn, in the same period the experimental yield for the main group of check varieties has increased 104 kg/ha/year (Macedo 2014). In this paper we study, for a series of 20 rice seasons, the productive performance of commercial varieties under experimental conditions in relation to climatic factors, with the aim of understanding the interaction between genotypes and environment; this allows the generation of new working hypotheses in genetic improvement as well as guidance in general crop management guidelines.

2. Materials and Methods

Data from 20 years of the Final Evaluation stage of advanced and elite cultivars of the Rice Breeding Program (PMGA) of INIA Treinta y Tres at the Paso de la Laguna Experimental Unit (UEPL) are analyzed. The management of these experiments is done as standard for rice practices in the country, including direct seeding at rates of 130-150 kg/ha, complete chemical weeds control, split fertilization of 70-100 kg total N/ha, approx. 50 kg/ha of P2O5 at sowing, full irrigation from 30-40 days post-emergency and without fungicide either insecticides applications. At least two seeding time were accomplished every season. The climatic information was extracted from the agroclimatic data bank of the INIA GRAS Portal, collected at the INIA Treinta y Tres station (33S, 54W). For this work, we collected daily data of maximum (TMAX) and minimum (TMIN) temperatures, number of days with a minimal temperature below 15 °C (DIAS T <15) and solar radiation (RAD [cal/cm2/day]) from the rice seasons of 1996-1997 to 2015-2016. The averages of these variables were estimated for four periods (0-3, Table 1), defined to assess the climatic impact on rice Yield and its components. The day recorded as "50% flowering" was taken as the "zero" day (heading), from which the reference periods were estimated and linked to the yield components that are mainly defined in each of them.

Table 1: Defined periods for evaluation of climatic factors on yield and yield components.

Period	Days	Yield Components
0	40-20 pre-heading days	Pan/m2, TotGr
1	20 pre-heading days	Pan/m2, TotGr
2	10 pre and 10 pos-heading days	%Ster, 1000GW
3	20 pos-heading days	1000GW

Pan/m2=number of panicles per square meter; TotGr=Total grains number per panicle; %Ster= percentage of unfiled grains; 1000GW= 1000 grains weight (grs)

Four cultivars were included as they were present on most of the serie: El Paso 144 (EP144) and INIA Olimar (Olimar), Indica subtype; INIA Tacuarí (Tacuarí) and Parao, Tropical Japónica subtype. The analysis was carried out with JMP 14.0 software (FTV), from SAS Institute Inc. To analyze the effects of components and climate on yield performance, an average of the repetitions of each experimental unit was used, then using Path Analysis. For its preparation, a model that estimates yield from registered yield components was adjusted, from which the standardized "beta" and the coefficient of determination R2 were obtained. The regression model used is: Y = a + bx + Ɛ; being: Y = yield, a =

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independent or intercept term, b = parameter (pending), being x = Pan/m2, TotGr, % Ster, 1000GW, Ɛ = experimental error.

On the other hand, a multiple regression model was first carried out using the Stepwise method for yield components based on climatic variables. The mixed methodology was used. This method selects some variables of all possible for all periods under consideration. The regression model used was: Y = a + bx + Ɛ; being Y = Pan/m2, TotGr, % Ster, P1000, a = independent term or intercept; b = parameter (pending); x = TMIN, TMAX, RAD, DAYS; Ɛ = experimental error. A model was also adjusted for Yield based on climatic variables, with the same methodology as for yield components based on climatic variables.

3. Results

Under the conditions of the East region of Uruguay, rice crop yield varies according to seeding time (ST) (Figure 1) as reported by Pèrez de Vida (2010); likewise, in this series, it results a significant interaction with the rice subtype. In “early” ST (defined until October 15) there are no statistical differences between the subtypes, although the average of the Indica was 400 kg/ha greater. In “intermediate” ST (October 15-November 15) the differences are not significant, with means differing by only 200 kg/ha. The yield in the set of sowings until “15-Nov” is maximized with Indica genotypes. In contrast, the difference between subtypes is significant in “late” ST (after November 15), in which the Japonica subtype significantly over yields (as by 600 kg/ha) the Indica subtype (Figure 1).

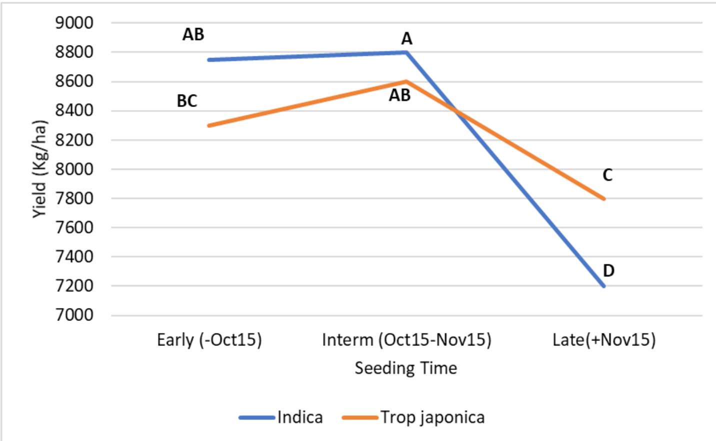

Figure 1: Yield according to seeding time and rice subtype (Indica [cultivars El Paso 144, INIA Olimar], and Tropical japonica [INIA Tacuarí and Parao]) and three seeding times (early, intermediate and late), in 20 years (from 1996/97 to 2015/16) at, Paso de la Laguna Experimental Unit, Treinta y Tres, Uruguay. (Letters indicate separation of means by Student's t-test, levels not connected by the same letter are significantly different α = 0.05).

The variations in yield linked to ST in Fig 1, are a function of the variation in climatic variables associated with the rice life cycle, given the time of planting of the genotypes. The path analysis diagram is shown in Figure 2, explaining grain yield based on climatic factors. The most important factors were selected by stepwise method, thus defining TMIN2 and RAD2 as being causally associated with variations in Yield; sun radiation around flowering (+/- 10 days) is the most important variable (as reported by Stansel (1975), Macedo (2014)).

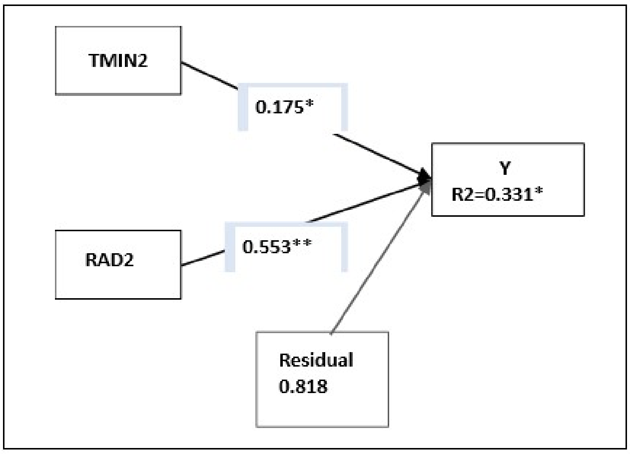

Figure 2: Yield as explained by climatic variables for cultivars Indicas (El Paso 144, INIA Olimar) and Tropical japonicas (INIA Tacuarí and Parao) and three planting times (Early, Intermediate and Late), in 20 years (from 1996/97 to 2015/16) at Paso de la Laguna Experimental Unit, Treinta y Tres Uruguay.
(* and **, represents significant with P = 0.05 and P = 0.01, respectively).

Paths diagrams for grain Yield are presented (Figure 3) according to its components (panicles/m2, total grains per panicle, % grain sterility and weight of 1000 grains), and in turn the model explaining the variations in these components based on climatic variables (only a significant one is showed). These considered climatic variables were those relevant at the definition time of the components (e.g. weight of 1000 grains would be mainly influenced by post-flowering environmental conditions); in table 2 are presented the direct and indirect effects of the components on Yield.

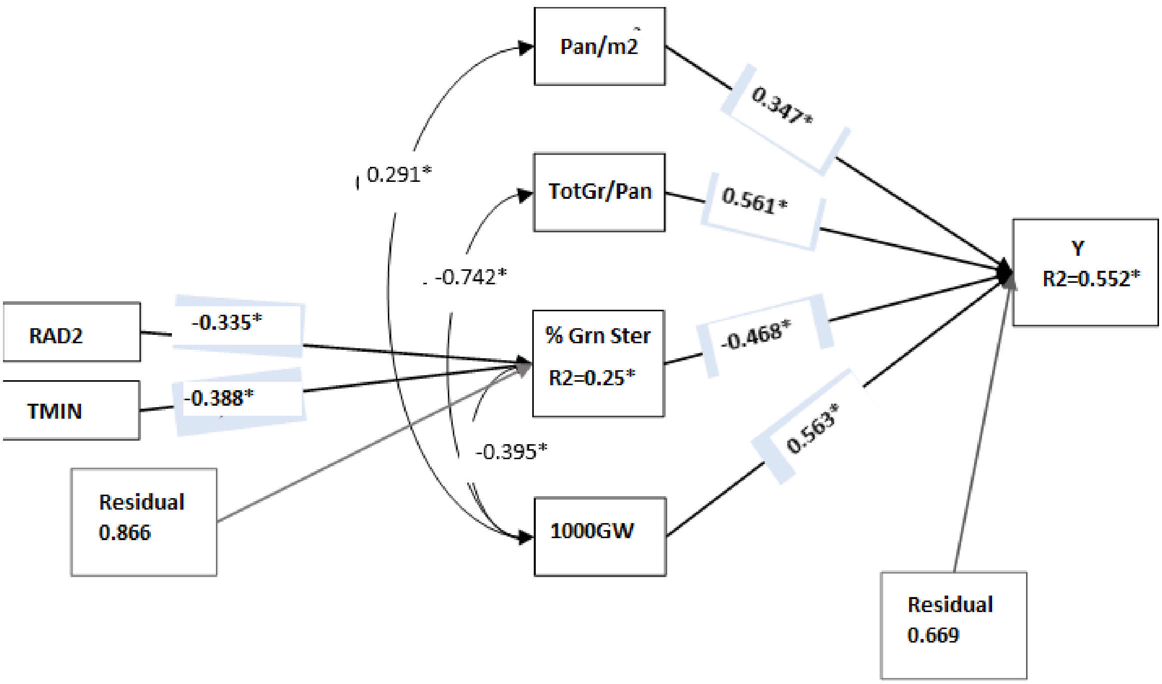

Figure 3. Diagram of path analysis for Yield (Y) as function of yield components, and effects of climatic variables on yield components (only significant at P=0.05 model is showed) for all cultivars (Indicas and Tropical Japonica) and seeding times. (Numbers in boxes of single head-arrows indicates values of path coefficients, numbers on double head-arrows indicates correlations coefficients) (* Significant with P = 0.05)

According to these results, all components have a significant direct effect on grain yield; being the weight of 1000 grains (P1000) and total grains per panicle (TotGr) which have "standardized beta" of greater absolute value. However, when considering the indirect effects, the TotGr component loses that importance, due to the strong indirect effect through 1000GW (high negative correlation between these components). In this balance of direct and indirect effects (those through the variables (components) with which it is correlated, it turns out that the most important component is % of sterile grains, with the highest sum of direct and indirect effects: -0.635. On the other hand, Pan/m2 and 1000GW have a similar overall effect, both positive and relevant, indicating the importance on Yield of high effective tillering and the weight of grains, with little interaction with climatic variables (Table 2). In relation to these, only the component "% grains sterility" is significantly affected. RAD and TMIN variables at period 2 (20 days around heading time), have both a numerically similar "beta" standardized coefficient and of equal sign (negative) (Figure 3).

Table 2: Direct, indirect and total effects of yield components on rice yield.

	Pan/m2	**TotGr/Pan**	**% grn ster**	**1000GW**
Direct	0,347	0,561	-0,468	0,563
Indirect	0,065	-0,500	-0,167	-0,130
Total Efect	**0,412**	0,060	**-0,635**	**0,433**

Conclusions

Rice production is maximized when the crop is sown in early or intermediate dates (1/10 to 15/11), while in late sowing the yield decreases significantly due to worse environmental conditions (temperature and radiation) at times of critical importance for the crop; yield of Tropical Japonica subtype decreases less than of Indica subtype cultivars. However, a greater proportion of yield variations are explained by variations in sun radiation, and less by low temperatures. Considering all ST the % grn ster is the component whose variations explain largely yield; otherwise, % grn ster was explained by variations in minimum temperature and radiation around flowering. Indeed, variables RAD and TMIN at 20 days around flowering were the most important climatic factors associated to the variation of crop yield. ST conditions the expected availability of environmental resources for whole crop; the earlier ST (October) would increase the available radiation in the period of critical importance (approx. 1st half of January), as well as later for grain filling period. Both, early and intermediate ST also decrease the incidence of low temperatures and therefore the % of grains sterility is minimized, resulting on larger crop yields.

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Rice Ecophysiology: Climatic Variables and Yield at Uruguay

INIA URUGUAY

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Introduction

In the last 20 years the national rice yield has increased at a rate of approx. 150 kg/ha/year, explained by the adoption of high yielding cultivars, improved cultural practices and favorable environmental conditions; average national yields in Uruguay at the last six rice seasons was in the range 8.1-8.6 t/ha. In turn, in the same period the experimental yield for the main group of check varieties has increased 104 kg/ha/year.

In this paper we study, for a series of 20 rice seasons, the productive performance of commercial varieties under experimental conditions in relationship to climatic factors, with the aim of understanding the interaction between genotypes and environment; this allows the generation of new working hypotheses in genetic improvement as well as guidance in general crop management guidelines.

Material and Methods

Data: 20 years data from the Final Evaluation stage of advanced and elite cultivars of the Rice Breeding Program INIA Treinta y Tres, rice seasons of 1996-1997 to 2015-2016. **Location**: Paso de la Laguna Experimental Unit (UEPL) 33S 54W. **Management**: as standard for rice practices in Uruguay, in two seeding times. **Cultivars:** El Paso 144 and INIA Olimar, Indica subtype; INIA Tacuarí and Parao, Tropical Japónica subtype. **Climatic information**: averages maximum (TMAX) and minimum (TMIN) temperatures, number of days with a minimal temperature below 15 °C (DIAS T<15) and solar radiation (RAD [cal/cm2/day]), estimated for four periods (0-3, Table 1), defined to assess the climatic impact on rice yield and its components.

Table 1: Defined periods for evaluation of climatic factors on yield and yield components.

Period	Days	Yield Components
0	40-20 pre-heading days	Pan/m2, TotGr
1	20 pre-heading days	Pan/m2, TotGr
2	10 pre and 10 pos-heading days	%Ster, 1000GW
3	20 pos-heading days	1000GW

Pan/m2=number of panicles per square meter; TotGr=Total grains number per panicle; %Ster= percentage of unfiled grains; 1000GW= 1000 grains weight (grs)

Data analysis: Path Analysis (JMP 14.0 FTV from SAS Institute Inc). Standardized beta and coefficient of determination (R2) obtained from:

1.a. Model that estimates yield from yield components: Y = a + bx + Ɛ; being Y = yield, a = intercept, b = parameter (pending), x = Pan/m2, TotGr, % Ster, 1000GW, Ɛ = experimental error.

1.b. Multiple regression model using the Stepwise method for yield components based on climatic variables, using mixed methodology, which selects some variables of all possible for all periods under consideration. Regression model: Y = a + bx + Ɛ; being Y = Pan/m2, TotGr, % Ster, P1000, a = intercept; b = parameter (pending); x = TMIN, TMAX, RAD, DAYS; Ɛ = experimental error.

2. Model for yield based on climatic variables, with the same methodology as in model 1.b.

Results

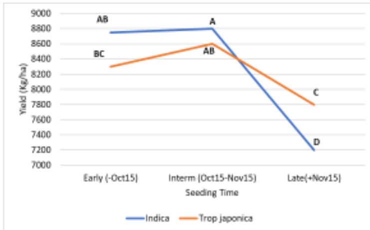

Figure 1. Yield according to seeding time and rice subtype
Letters indicate separation of means by Student's t-test, levels not connected by the same letter are significantly different α = 0.05

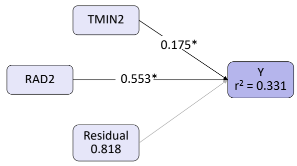

Figure 2: Yield as explained by climatic variables (* significant with P = 0.05)

Yield variations are explained in a greater proportion by sun radiation, and also by low temperatures. Grain sterility is the component whose variations explain largely yield. Otherwise, grain sterility was explained by variations in minimum temperature and radiation around flowering. Indeed, these variables were the most important climatic factors directly associated with crop yield variations.

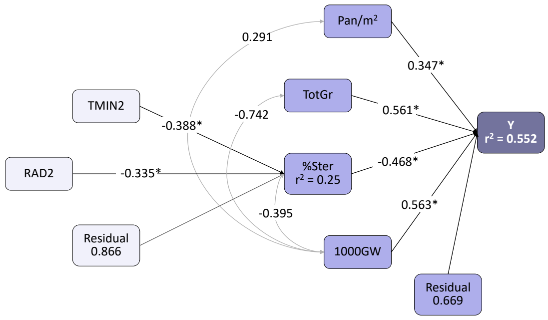

Figure 3. Diagram of path analysis for Yield (Y) as function of yield components, and effects of climatic variables on yield components.
Numbers in boxes of single head-arrows indicates values of path coefficients, numbers on double head-arrows indicates correlations coefficients. * Significant with P = 0.05

Rice production is maximized when the crop is sown in early-intermediate dates (1/10 to 15/11), decreasing in late sowing due to worse environmental conditions (temperature and radiation) at times of critical importance for the crop; yield of Tropical Japonica subtype decreases less than of Indica subtype cultivars.

Conclusions

Seeding time conditions the expected availability of environmental resources for whole crop; the earlier seeding times (October) would increase the available radiation around the period of most critical importance (heading), as well as later for grain filling period. Early and intermediate seeding time decrease the incidence of low temperatures and therefore the grain sterility is minimized, resulting on larger crop yields.

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Embrapa ITRC International Temperate Rice Conference INIA URUGUAY SOSBAI

Delivering premium japonica product from Australian rice production- not all it's cracked up to be.

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ABSTRACT

Record high yielding japonica varieties have emanated from the Australian breeding and quality programs over the last 20 years. However as growers yield's exceed 14 t/ha, maintaining quality reliably for selected value adding clientele has become difficult due to extensive losses attributed to grain cracking. A focus has emerged on ensuring consistent grain quality, particularly whole grain integrity, from pre-harvest management to post-milling storage for Australian premium japonica varieties. Two trials were undertaken to quantify the role of rate of post-harvest drying on aspects of grain quality linked to consumer preferences. In particular the influence of rapid drying on the degree of "Hanasaki" cracks, or those formed once milled whole-grain was soaked.

Reduction of grain moisture by 9% (rapid) and 3% (standard) (wet basis) per 12 hours were implemented on field samples harvested at different stages of grain maturation over two seasons at the same site, for a subsample of short and bold-medium grain varieties. Consistent significant trends were noted on both physical grain quality attributes, most notably grain color and dimension, and cooking attributes including peak viscosity and cooled gel consistency. The degree of "Hanasaki" cracks decreased significantly in one season from rapid drying. The consequence of these effects on the desirability of product to the end point clientele is discussed.

Key words: "Hanasaki" cracks, "Value added",.

1. Introduction

Australian rice varieties are known for high quality. One important determinant of the quality of milled rice is the amount of unbroken grains, which constitute the whole grain returns upon milling. Cracked or poor quality paddy grains reduce whole grain returns (WGR) and result in lower profits to farmers and processing industries, since rice is primarily consumed as a whole grain product (Bhattacharya 2011). For the more lucrative markets, soaking of whole, milled grain is a common practice for value-added production like parboiling, retorting, flaking, puffing and cooking (Oli, Ward, Adhikari, & Torley, 2014). Soaking of rice prior to processing or cooking distributes moisture more evenly throughout the grain, thereby saving time and energy.

Ward *et al*. (2019) has recently demonstrated the variability of WGR and other grain quality attributes across the Australian production environments. Influences of thermal time has been demonstrated to work against WGR for the soft cooking variety types routinely bred in the Australian program (Balingdong *et al*. 2018). With the influence of nitrogen although initially beneficial to WGR, being demonstrated to have adverse consequences to grain quality after storage of Australian premium medium and short grain varieties (Oli et al. 2019)

The experimental work discussed here was instigated to investigate the influence of rate of post-harvest drying on rice grain quality of an elite set of commercial japonica bold medium grain and short-grain commonly utilised by key clientele. In addition to the commonly measured physical grain quality parameters and cooking qualities, propensity of whole-milled grain to cracking after soaking ("Hanasaki" cracks) was also assessed. Hanaksai cracks are an undesirable consequence of soaking low-moisture polished grains in water, resulting in a partial splitting of the grain and leading to leaching of starch, and a reduction in the ability of cracked soaked grain to hold together during subsequent cooking and processing (Genkawa *et al*. 2011; Koide *et al*. 2001). Hanasaki measurement is a quality assessment used by the Australian rice industry for short and some medium grains, where the end-use requires soaking or washing in water (e.g., in traditional Sushi preparation). There are indications that the quality of cooked rice (as measured by sensory and texture parameters) is decreased when Hanasaki-cracked grain exceeds 10% (Koide, 2010).

2. Material and Methods

Temperate japonica breeding lines (Table 1) from the Australian rice breeding program field trials grown at Leeton Field Station, Leeton, NSW Australia (latitude: 34.60 °S, longitude: 146.40 °E) were used in this study. The trial consisted of a random complete block design with three replicates for each variety that were sequential harvested throughout grain ripening on a 10 day cycle as noted in previous proceedings (Ovenden *et al*. 2014). To encompass the full gambit of whole grain scenarios two different harvest dates were chosen, one close to physiological maturity (26-22%) for which optimal WGR (2015) would be expected and one where several cycles of drying and rewetting were encountered and WGR were likely to be low (2016). In both cases two drying treatments per field replicate were introduced, one “Rapid” in which a mono-layer of grain in perforated drawers was subjected to fan forced drying at 40ºC for 12 hours, the other was a “Standard” practice used by the breeding program in which 300g of paddy was slowly dried in paper bags on racked tables in an air-conditioned lab (21ºC for 12 hours). Grain moisture was recorded (Cropscan, NSW, Australia) for each sample at the beginning and end of each treatment, with tempering, cleaning and milling proceeding as per protocols of our Quality Evaluation Program (QEP), noted elsewhere (Ward *et al*. 2019).

In addition to the standard physical (whole grain, chalk, colour and grain dimension) and wet chemistry parameters (Amylose, protein, gel temperature and RVA) routinely recorded through the QEP, attributes relevant to end point users, particularly formation of cracks under absorption method of cooking (“Hanasaki” cracks) and cooled gel consistency (“Adhesions”), were also recorded. A two-factor analysis of variation (ANOVA) was carried out within each of the two years.

Hanasaki is measured by visually recording the percentage of cracked grain after soaking 100 grains in water for 1h.

3. Results

Differences in WGR were noted between years, 2015 having 70% and 2016 only 38% as expected from the targeted subsample, however only variety differences were significant in the overall analysis. A significant difference was noted in both seasons in the drying regimes with grain moisture decreasing about three fold that of the “Standard” grain drying procedures across the 2 years (Table 1). Although interactions between Treatment and variety were noted in the second year, this was of non-crossover interaction type (data not shown). Significant treatment and variety effects were attributed to all grain quality attributes listed in Table 1, with the exception of Treatment effects in “Hanasaki” cracks and varietal effects in Adhesion both in 2015, in both instances significant replicated effects were also noted. Significant Treatment effects not listed in Table 1, was a consistent softer texture profile from RVA of the “Rapid” drying treatment, with no significance differences in apparent amylose, although significant difference in protein content did seem a likely cause of this effect.

4. Discussion

Effects of rate of paddy drying on WGR is far from a new concept in the literature (eg Fan *et al.* 2000), however the ramifications of these treatments post milling in the hands of value-added clientele is far from understood. Interestingly despite no difference in WGR between rates of drying in the current study, other grain quality parameters were significantly affected that would influence desirability to the end-point user. On initially milled grain appearance for example higher degree of whiteness (L*) is desired, while grain length (Len) is used to differentiate short and medium grain varieties with all of these parameters often used to discriminate between different geographical nodes of production (Pantindol *et al*. 2016). For grain integrity through processing and end-point utility "Value-added" clientele generally stipulate low thresholds in both "Hanasaki" cracks and Adhesiveness (retrogradation or "staling"), as "Sushi Factories" for example requires consistent finished product (FP) given the difficulties in fine tuning automation by batch run of raw product. Current season's trials are underway to validate some of the findings in this pilot study, with more locations and more sampling through a range of moisture through the grain maturation and dry down process targeted. The role of lipids, protein and the composition of protein (eg. Balingdong *et al*. 2018) also warrant further investigation.

Table 2. Summary statistics

	Rate of Drying		*L**(colour)		Len (mm)		Hanaskai Crk		Adhesion	
Statistic	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
SOURCEs										
Treatment	P<0.01	P<0.01	P<0.01	P<0.02	P<0.05	P<0.05	NS	P<0.01	P<0.01	P<0.02
Rep/Trt	NS	NS	NS	NS	NS	NS	P<0.02	NS	P<0.02	NS
Variety	P<0.03	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.05	P<0.01	NS	P<0.01
Trt x Var	NS	P<0.02	NS	NS	NS	NS	NS	NS	NS	NS
MEANS										
Rapid	9.07	9.53	69.93	72.84	5.06	5.46	21.07	10.33	183.09	196.35
Standard	1.78	2.50	69.29	73.46	5.10	5.51	25.20	14.71	229.57	185.52
LSD (0.05)	0.61	0.69	0.43	0.48	0.30	0.04	NA	2.82	27.97	8.99
Koshihikari	-	6.52	-	73.14	-	4.65	-	26.19	-	175.92
Opus	5.05	6.37	70.19	72.81	4.66	4.68	29.25	18.23	229.35	186.67
Reiziq	6.22	8.07	69.21	72.93	5.90	5.96	25.67	7.15	193.38	183.17
Sherpa	5.92	7.63	69.77	73.83	5.35	5.36	20.71	4.86	233.10	196.32
Uraraka	5.13	4.77	69.03	71.97	4.75	4.88	20.51	12.93	176.85	190.70
V18	4.80	-	69.85	-	4.71	-	19.54	-	198.95	-
Viand	-	6.02	-	74.21	-	5.58	-	5.76	-	212.85
LSD (0.05)	1.37	1.19	0.69	0.84	0.06	0.09	7.12	4.88	NA	15.57

Conclusions

Australian premium japonica varieties has been a world leader in tonnage per area for a number of years, however the pre and post-harvest practices that accompanies such volumes of productions need to be address to ensure WGR returns are at their optimal for a sustainable crop choice for irrigator farmer and a high returning commodity stream for the industry. The worked was instigated to investigate the effect of rate of post-harvest drying on grain quality attributes beyond WGR, but pertinent to more selective end point clientele. Two years of experimentation in the same location over a similar cohort of premium japonica varieties at either ends of the grain maturation process resulted in some consistent and commercially significant trends.

As the rate of drying had significant influence on pivotal grain quality attributes for "Value added" clientele, work is on-going to ensure optimal variety by post-harvest practices are understood and implemented for future seasons.

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Irrigated rice seed quality, Epagri cultivars, in function of harvest time.

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ABSTRACT

All advances in genetics in the development of new cultivars are transferred to grain production, for the benefit of the farmer, through the seeds. The use of high quality seeds of known and reliable origin are basic prerequisites for management strategies aimed at increasing productivity, competitiveness and sustainability of rice cultivation. Harvesting at the right time has fundamental importance in order to obtain better quality seeds with higher yields. Early harvesting, with high humidity, increases the proportion of malformed and chalky seeds. The objective of this study was to evaluate the harvest period of Epagri rice cultivars in order to estimate the moment that the seeds presents better physiological quality and estimate the relationship between seed quality traits. The experiment was in a randomized blocks with three replicates. The cultivars used was Epagri 106, Epagri 109, SCSBRS Tio Taka, SCS116 Satoru, SCS118 Marques, SCS121 CL and SCS122 Miura. Five harvests were done from 25 to 45 days after flowering (DAF). It can be verified that for all long-cycle cultivars, the most suitable period for harvesting was when the seed moisture was between 20-24%, around 35-40 DAF, during which period the seeds showed higher vigor, germination, percentage of whole seeds and lower level of chalky. While the medium-cycle cultivar Epagri 106, with the exception of germination, all other traits behaved similarly at all harvest times. Early harvests were inadequate, which resulted in high humidity and low physical and physiological seed quality. Percentage of whole grains presented direct relation with germination and seed vigor.

Key words: seed vigor, broken seeds, *Oryza sativa* L.

NEW RICE COLUMNAR IDEOTYPES AND ITS INTERACTION WITH REDUCING ROW SPACING

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ABSTRACT

During several rice-growing seasons, we have tested a new plant ideotype sowed in a narrow lines system. In all environments, an improvement of agronomical yield was obtained using a reduce row system either we have used traditional or columnar genotypes. Despite this, better performance was registered with columnar genotypes. A combination of new agronomical practices with a columnar type genotype would increase productivity limits.

Keywords: rice, ideotype, row spacing, yield

Introduction

In crop plants, differences in architecture and changes in architecture can have a profound impact on crop performance and productivity (Bai et al., 2018). Quantitative leaps in rice yield have been achieved through changes in cultivated plant architecture (Khush, 1995). During the sixties and seventies, grain rice world production was doubled thanks to the design and implementation of semi-dwarf varieties. The generation of these cultivars responds to breeding based on a model of plant (Jennings, 1964). The construction of this model requires a deep knowledge of the morphological, physiological characters and intervening genetic bases to predict their performance in a given environment, agronomic practice or combination of both (Donald, 1968; Martre et al.,2015). Rice breeding division at INTA Concepcion del Uruguay, obtained through anthers cultivation, genotypes with particular characteristics in the canopy, reproductive structure and stem compared to a modern plant type of current commercial cultivars (IRGA 424 RI, GURI INTA CL, and PUITA INTA CL). Using selection based on ideotype breeding, genotypes have been designed with extremely erect leaf angles, wide leaves, stay green, disease resistance, intermediate tillering, compact panicles, prolonged grain filling and stems reinforced with imbricated sheaths. Our plant model responds to a highly photosynthesizing, non-competitive plant that uses natural resources to the maximum, and optimizing input applications. It has been developed to improve the spatial ordering of plants per square meter using a reduction in row spacing traditionally used in Argentina. With stagnant yields and a crisis installed in the Argentinian rice crop, combining columnar genetics and new agronomical practices would provide a solution to the increase in grain production and the crop profitability. The aim of this study is to evaluate the new plant ideotype in different rice production systems.

Materials and methods

Next, a series of trials with different columnar lines, row distances, locations and years will be presented.

Cropping season 16-17

Two direct seed sowing systems were evaluated. A conventional (20 cm. between row) and double-crossing sowing with an angle of 30º to simulate a reduction in row spacing. The columnar line, CR 2006, was used to assess its yield potential in both systems. The Experimental trial, one hectare, was sown in Las Palmas Chaco (27 ° 2 ′ 56 ″ S, 58 ° 40 ′ 58 ″ W) on November 4, 2016. We used a seeding rate of 110 kg*ha^{-1}. Four levels of fertilization with urea (0, 80, 160 and 240 kg*ha^{-1}) were established for each planting system at the pre-irrigation stage. Two plots of 400 m^2 were harvested per treatment in both planting systems. Performance data were analyzed using an analysis of variance.

Cropping season 17-18

Five genotypes were analyzed, three advanced lines with columnar structure (CR 2204, CR 2212 and CR 1044), the variety GURI INTA CL and the hybrid INOV CL (RiceTec). The trial was sown in the EEA Corrientes (S27 ° 28'50.16 ", O58 ° 50'2.76") on November 1, 2017. Two planting distances (11 and 21 cm) in the experimental plot were evaluated. Performance data were analyzed using an analysis of variance.

Cropping season 18-19

The new rice cultivar MEMBY PORA INTA CL (conventional plant ideotype) was evaluated under two different row spacing, 15 cm, and 20 cm. The assay was sown in the EEA Concepción del Uruguay (S32 ° 28'56.96 ", O58 ° 14'13.99") on September 22, 2018. The seeding rate was 97 kg*ha^{-1} of seed, maintaining the same in both distances. The fertilization treatments proposed were: T1, without nitrogen addition; T2, 70 kg*ha^{-1} of N (pre-irrigation); T3, 70 kg*ha^{-1} of N (pre-irrigation) + 50 kg*ha^{-1} of N (differentiation); T4, 140 kg*ha^{-1} of N (pre-irrigation) and T5, 140 kg*ha^{-1} of N (pre-irrigation) + 50 kg*ha^{-1} of N (differentiation). The variables analyzed were agricultural yield and industrial yield through an analysis of variance.

Results and Discussion

Cropping season 16-17

The crop showed adequate development in both systems. Forty days after the emergency, greater coverage in the plots of the cross-sowing system was observed.

Row distance	
Conventional	6557.4 b
Double-crossing	9761.3 a
Fertilization	
0 kg*ha^{-1}	7400.3 b
80 kg*ha^{-1}	8112.0 ab
160 kg*ha^{-1}	8257.5 ab
240 kg*ha^{-1}	8867.5 a

Table 1. Tukey (P> 0.05) Different letters in the columns indicate significant differences

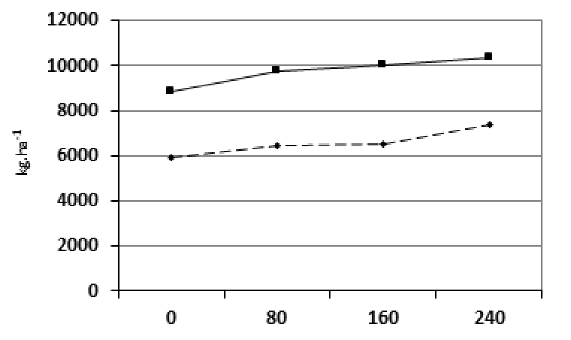
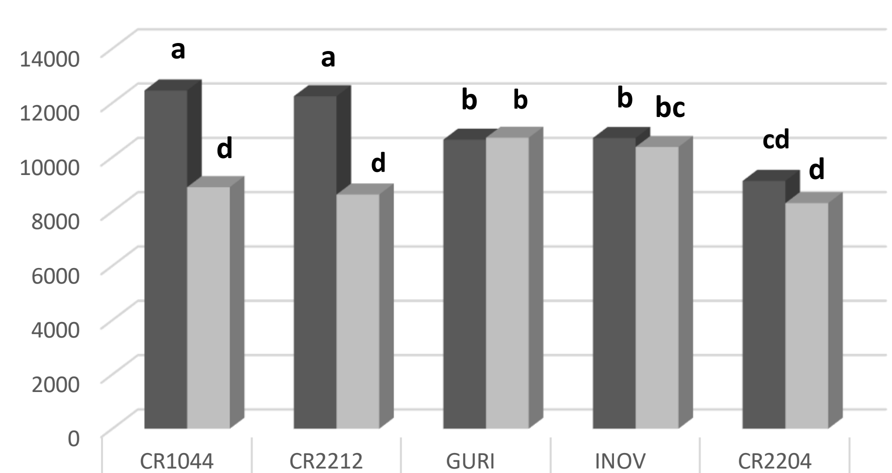


Figure 1. Fertilization treatment response for fertilizer levels applied. Continuous lines indicate the cross-system, intermittently the conventional system. Chaco (2016-2017).

The double-crossing system had a significant effect on the grain yield increasing 48% on average of all fertilization treatments evaluated.

Cropping season 17-18

In the trial conducted during the 2017-2018 cropping season, a significant increase in grain yield for distancing was again evident. The distance between rows of 11 cm had a significant average difference of 1650 kg*ha^{-1} (18 %) compared to the distance at 21 cm.



	CR1044	CR2212	GURI	INOV	CR2204
11	12456	12244,67	10644,33	10707,67	9125,33
21	8897	8626,33	10717	10377	8309,33

Figure Nº2. Analysis of variance for genotypes in different sowing systems. Duncan test (α = 0.05). Stockings with a common letter are not significantly different.

The columnar lines Cr 1044 and Cr 2212 obtained the highest yield. The increase in favor of narrow sowing was 40 percent compared to the conventional system in both lines (Figure n°2).

Cropping season 18-19

In the 2018/2019 growing season, the Memby Porá INTA CL variety greatly increased its yield under the narrowest planting system (Table 2). The higher-yielding is mainly-explained by the variable number of panicles by area.

The rice milling quality parameters were evaluated in this essay. No differences were found for the head rice yield variable and milled rice yield for both spacing treatment. However, significant differences were observed in favor of the 15 cm spacing for the chalkiness and white belly variables (Table 2).

Table 2: ANOVA and Average Test: Yield, Panicle, 1000 grains weight, Head Rice Yield (HRY), Milled Rice Yield, Chalky Grains and White belly.

				Milling Quality			
	Yield (Kg/ha)	Panicles/m^2	GW (gr)	HRY (%)	MRY (%)	*Chalkiness (%)	**White belly (%)
SPACING							
15 cm	10093 **a**	500 **a**	24,53 **a**	65,94 **a**	69,18 **a**	0,70 **a**	3,21 **a**
20 cm	8012 **b**	460 **a**	24,34 **a**	65,21 **a**	69,08 **a**	1,19 **b**	4,77 **b**
FERTILIZATION							
Check	7097 **b**	412 **b**	24,62 **a**	63,29 **c**	68,51 **c**	1,76 **b**	6,20 **b**
70 Kg N	8324 **b**	484 **ab**	24,64 **a**	65,68 **b**	69,27 **ab**	0,73 **a**	3,84 **a**
70 Kg + 50 Kg N	9764 **a**	486 **ab**	24,35 **a**	65,56 **b**	69,17 **b**	0,93 **a**	3,59 **a**
140 Kg N	9969 **a**	493 **ab**	24,43 **a**	65,81 **b**	69,19 **b**	0,65 **a**	3,48 **a**
140 Kg + 50 Kg N	10107 **a**	524 **a**	24,14 **a**	67,54 **a**	69,54 **a**	0,65 **a**	2,85 **a**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Conclusions

Narrow row spacing increases significantly the grain yield in both, conventional plant ideotype and columnar lines.

The increase in grain yield is considerably higher in columnar ideotypes.

Narrow row spacing does not compromise head rice yield and milled rice yield values, and favored the values chalky grains and white belly values in the cultivar Memby Pora INTA CL.

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NEW RICE COLUMNAR IDEOTYPES AND ITS INTERACTION WITH REDUCING ROW SPACING

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Introduction

In crop plants, differences in architecture and changes in architecture can have a profound impact on crop performance and productivity (Bai et al., 2018). The rice breeding division at INTA Concepcion del Uruguay, obtained through anthers culture, genotypes with particular characteristics in the canopy, reproductive structure and stem compared to a modern plant type of current commercial cultivars (IRGA 424 RI, GURI INTA CL, and PUITA INTA CL). This new plant type has been developed to improve the spatial ordering of plants using a reduction in row spacing traditionally used in Argentina. With stagnant yields in Argentina, combining columnar genetics and new agronomical practices would contribute to increase rice yield and the crop profitability.

Columnar ideotype features

- Extreme erect leaf angles
- Wide leaves
- Compact panicles
- Plant height 100-120 cm
- Strong culm (imbricated sheaths)
- Stay green
- Longer grain filling stage

Objective

The aim of this study was to evaluate the new plant ideotype in different rice production systems.

Material and Methods

Following, a series of trials with different columnar lines, row distances, locations and years will be presented.

Cropping season 16-17

Two direct seed sowing systems were evaluated. A conventional (20 cm. between row) and double-crossing sowing with an angle of 30º to simulate a reduction in row spacing. The columnar line, CR 2006, was used to assess its yield potential in both systems. The Experimental trial, one hectare, was sown in Las Palmas Chaco (27 ° 2 ' 56 " S, 58 ° 40 ' 58 " W) on November 4, 2016. Two plots of 400 m2 were harvested per treatment in both planting systems. Performance data were analyzed using an analysis of variance

Cropping season 17-18

Five genotypes were analyzed, three advanced lines with columnar structure (CR 2204, CR 2212 and CR 1044), the variety GURI INTA CL and the hybrid INOV CL (RiceTec). The trial was sown in the EEA Corrientes (S27 ° 28'50.16 ", O58 ° 50'2.76") on November 1, 2017. Two planting distances (11 and 21 cm) in the experimental plot were evaluated. Performance data were analyzed using an analysis of variance

Cropping season 18-19

The new rice cultivar MEMBY PORA INTA CL (conventional plant ideotype) was evaluated under two different row spacing, 15 cm, and 20 cm. The assay was sown in the EEA Concepción del Uruguay (S32 ° 28'56.96 ", O58 ° 14'13.99") on September 22, 2018. The variables analyzed were agricultural yield and milling yield using an analysis of variance.

Results

Cropping season 16-17

The double-crossing system had a significant effect on the grain yield increasing 48% on average of all fertilization treatments evaluated

Row distance	
Conventional	6557.4 b
Double-crossing	9761.3 a
Fertilization	
0 kg*ha^{-1}	7400.3 b
80 kg*ha^{-1}	8112.0 ab
160 kg*ha^{-1}	8257.5 ab
240 kg*ha^{-1}	8867.5 a

Table 1. Tukey (P> 0.05) Different letters in the columns indicate significant differences

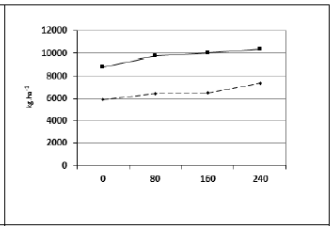

Figure 1. Rice yield vs fertilization treatments. Continuous line indicates the cross-system, and dot line the conventional system. Chaco (2016-2017).

Cropping season 17-18

A significant increase in grain yield for row spacing was again evident. The distance between rows of 11 cm had a significant average advantage of 1650 kg*ha-1 (18 %) compared to the distance at 21 cm.

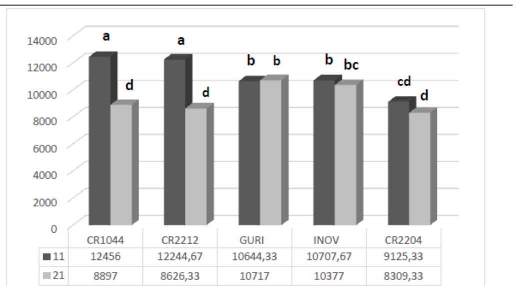

Figure Nº2. Analysis of variance for genotypes in different sowing systems. Duncan test (α = 0.05). Stockings with a common letter are not significantly different.

Cropping season 18-19

The variety Memby Porá INTA CL greatly increased its yield under the narrowest planting system (Table 2).

Table 2: ANOVA and Average Test: Yield, Panicle, 1000 grains weight, Head Rice Yield (HRY), Milled Rice Yield, Chalky Grains and White belly.

				Milling Quality			
	Yield (Kg/ha)	Panicles/m^2	GW (gr)	HRY (%)	MRY (%)	*Chalkiness (%)	**White belly (%)
SPACING							
15 cm	10093 **a**	500 **a**	24,53 **a**	65,94 **a**	69,18 **a**	0,70 **a**	3,21 **a**
20 cm	8012 **b**	460 **a**	24,34 **a**	65,21 **a**	69,08 **a**	1,19 **b**	4,77 **b**
FERTILIZATION							
Check	7097 **b**	412 **b**	24,62 **a**	63,29 **c**	68,51 **c**	1,76 **b**	6,20 **b**
70 Kg N	8324 **b**	484 **ab**	24,64 **a**	65,68 **b**	69,27 **ab**	0,73 **a**	3,84 **a**
70 Kg + 50 Kg N	9764 **a**	486 **ab**	24,35 **a**	65,56 **b**	69,17 **b**	0,93 **a**	3,59 **a**
140 Kg N	9969 **a**	493 **ab**	24,43 **a**	65,81 **b**	69,19 **b**	0,65 **a**	3,48 **a**
140 Kg + 50 Kg N	10107 **a**	524 **a**	24,14 **a**	67,54 **a**	69,54 **a**	0,65 **a**	2,85 **a**
Interaction	NS	NS	NS	NS	NS	NS	NS

Also , no differences were found for the head rice and milled rice yield for both spacing treatments. Significant differences were observed in favor of the 15 cm spacing for the chalkiness and white belly variables (Table 2).

Conclusions

Narrow row spacing increases significantly the grain yield in both, conventional plant ideotype and columnar lines.
The increase in grain yield was considerably higher in columnar ideotypes.
Narrow row spacing does not compromise head rice yield and milled rice yield values, and registered lower values for chalky grains and white belly values in the cultivar Memby Pora INTA CL.

Performance of F6 generation lines selected for physical grain quality attributes in irrigated rice

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ABSTRACT

Characters of grain quality in rice obtained an importance within the breeding programs in a way equal to the grain yield. The objective of this work was to evaluate the performance of F6 lines from the rice breeding program of Embrapa, specifically selected for physical attributes of grain quality, in the 2017/2018 cropping season. The experimental design for this study was a randomized complete block with three replicates, with 19 genotypes evaluated. The characters of grains were evaluated in a S21 Statistical Analyzer equipment (LKL Technology) using samples of polished grains. Variables evaluated were Chalky Total Area, White Belly, Vitreous Whiteness, Color Defects, Whole Grains and Broken Grains. Data were subjected to statistical analysis (ANOVA) using the GENES statistical software. The selection of rice breedlines carried out was of great efficiency in the development of superior genotypes, especially regarding the physical attributes of grain quality.

Key words: grain quality, whole grains, vitreous grains, chalky grains, selection, rice.

1. Introduction

The grain quality of rice is a fundamental factor for its marketing, since whole- and flawless-grains have a higher market value. Due to this, the grain quality characters have gained space and importance within the breeding programs, in a such way equal to the crop productivity.

In the world there is not a single rice consumption pattern; in fact, exists a demand for various types of grain, with very diverse attributes from region to region. Consumers are very picky about grain quality. According to Streck et al. (2018) in Brazil, consumers prefer polished white rice of the long and thin class (subspecies *Indica*), which presents soft grains that remain loose after cooking.

Some studies indicate that it is possible to make early selections in segregating generations for grain quality traits in rice, even though they are qualitative traits controlled by many genes, both classical breeding or by using molecular markers as biotechnological tools (Asante, 2017; Terres et al., 2019).

The main characteristics of grain quality in rice sought by breeders are: chalky areas, being the opaque part of the rice endosperm and occurs due to disturbances in the arrangement of starch and protein molecules, becoming loosely organized with the space between molecules filled with air (Shen et al., 2000); whole grains or milled yield, are the main attribute of industrial quality, being the proportion (percentage) of grains that are whole, above 3.5 mm in length, after the husking and polishing process; and other color defects, being the sum of yellow grains, striped, bitten (by insects, leaving marks) and stained, which are considered inappropriate, requiring great efforts and technologies to remove them from whole grains and vitreous.

In this sense, the objective of this work was to evaluate the performance of lines F6, specifically selected for physical attributes of quality grain of irrigated rice in the state of Rio Grande do Sul, Brazil, in agricultural year of 2017/2018.

2. Material and Methods

The experiment was conducted in the 2017/2018 cropping season in the Lowlands Experimental Station of Embrapa, in Capão do Leão, RS, Brazil (31º48'59"S, 52º27'48"W) located in a traditional rice-producing area in the southern zone of Brazil.

The experimental design for this study was a randomized complete blocks with three replicates. The experimental units consisted of plots 5-m-long, with rice rows spaced at 0.17 m. Useful plot area consisted of the four central meters of the two internal rows. Irrigation was performed using permanent flood system until the final maturation stage of the genotypes. Seeding was performed at a density of 100 kg ha^{-1} of viable seeds, using a mechanical seed plotter in a conventional planting system. All cultural treatments, soil management, fertilization, disease control, pests and weeds were done according to the technical recommendations for cultivation of irrigated rice (SOSBAI, 2016).

Were evaluated 19 genotypes (Table 1). 15 of these where F6-generation lines specifically selected since F3 for attributes physical quality of grains, and four cultivars were used as control (BRS Pampa, BRS Pampeira, BR IRGA 409 and IRGA 417), all known for its high-quality grain to Brazilian consumption standards.

The characters were obtained in a S21 Statistical Analyzer equipment (LKL Technology) from polished grain samples. Characters evaluated were Chalky Area Total (CA-%), White Belly (WB-%), Vitreous Whiteness (VW), Color Defects (CD-%), Whole Grains (WG-%) and Broken Grains (BG-%). Data were subjected to analysis of variance and subsequent Scott-Knott clustering test at 5% probability ($p < 0.05$) using the GENES statistical software (CRUZ, 2013).

Table 1. Genotype list evaluated in the experiment

Treatments	Genotype	Genealogy
1	PH18101	BRS Pampa / 86014-TR891-7-2-1
2	BR IRGA 409	Control treatment
3	PH18102	BRS Pampa / 86014-TR891-7-2-1
4	PH18103	BRS Pampa / 86014-TR891-7-2-1
5	PH18201	86014-TR891-7-2-1 / BR IRGA 409
6	PH18202	86014-TR891-7-2-1 / BR IRGA 409
7	BRS PAMPA	Control treatment
8	PH18301	AB09025 / BRS Pampa
9	PH18302	AB09025 / BRS Pampa
10	PH18401	AB08020 / BRS Pampa
11	PH18402	AB08020 / BRS Pampa
12	PH18501	AB09025 / IRGA 417
13	IRGA 417	Control treatment
14	PH18502	AB09025 / IRGA 417
15	PH18601	AB 10010 / BRS Pampa
16	PH18602	AB 10010 / BRS Pampa
17	PH18701	BRA 050151 / BRS Pampa
18	BRS PAMPEIRA	Control treatment
19	PH18801	BRA 050151 / Puitá INTA CL

3. Results and Discussion

The analysis of variance (Table 2) showed that there was a significant difference by F test for five variables analyzed (CA, WB, VW, WF and BG), which presented coefficients of variation between 0.63% for the variable of vitreous whiteness and 66.73.6% for the variable white belly. There was a high heritability of the evaluated characters (between 77% and 93%), thus providing a high precision in the selection process, and showing that the variance of treatments corresponding to an elevated genetics factor of these variables. For the color defects variable, the analysis of variance showed no statistically significant effects, however, it is noteworthy that all genotypes presented averages with good grain vitreous appearance.

Table 2. Analysis of variance and estimates of heritability in irrigated rice regarding the quality grain characters Chalky Area (CA-%), White Belly (WB-%), Vitreous Whiteness (VW), Color Defects (CD-%), Whole Grains (WG-%) and Broken Grains (BG-%). Capão do Leão, RS, Brazil, 2018.

SV	DF	CA	WB	CD	VW	WG	BG
Block	2	0.97	0.01	0.04	3.32	3.99	2.26
Treatments	18	33.49**	0.70**	0.05^{ns}	8.39**	87.86**	32.66**
Error	36	5.02	0.16	0.05	0.59	16.91	6.01
Total	56						
Mean		16.2	0.59	0.52	122.3	55.0	11.7
CV(%)		13.8	66.7	43.3	0.63	7.5	21.0
h^2		85.0	77.7	3.5	93.0	80.7	81.6

SV – Sources of Variance; DF – Degree of freedom; CV - coefficient of variation; h^2 - heritability. **significant at the 5% probability level by the F test; ^{ns} not significant.

Table 3. Grain quality (Chalky Area (CA-%), White Belly (WB-%), Vitreous Whiteness (VW), Color Defects (CD-%), Whole Grains (WG-%) and Broken Grains (BG-%)) of genotypes of irrigated rice. Capão do Leão, RS, Brazil, 2018.

Treatment	Genotype	CA		WB		CD		VW		WG		BG	
3	PH18102	11.05	a	0.56	a	0.73	a	121.91	c	63.33	a	6.44	a
14	PH18502	17.25	c	0.33	a	0.42	a	123.21	c	62.38	a	8.30	a
8	PH18301	12.39	b	0.17	a	0.60	a	121.81	c	59.97	a	6.35	a
17	PH18701	17.02	c	0.61	a	0.44	a	122.63	c	59.24	a	8.66	a
7	BRS PAMPA	17.91	c	0.57	a	0.54	a	122.32	c	58.54	a	8.86	a
9	PH18302	8.94	a	0.19	a	0.46	a	117.61	a	57.47	a	9.65	a
11	PH18402	16.69	c	0.53	a	0.29	a	123.01	c	56.69	a	12.25	b
13	IRGA417	17.45	c	0.32	a	0.53	a	123.30	c	56.54	a	11.62	b
2	BR IRGA 409	18.44	c	0.55	a	0.52	a	123.04	c	55.80	a	10.36	a
19	PH18801	18.14	c	0.58	a	0.61	a	121.97	c	55.36	a	12.14	b
18	BRS PAMPEIRA	13.60	b	0.14	a	0.35	a	120.58	b	55.17	a	12.99	b
1	PH18101	13.85	b	0.31	a	0.38	a	122.49	c	55.06	a	11.23	b
12	PH18501	15.42	b	0.16	a	0.44	a	123.22	c	54.89	a	12.07	b
15	PH18601	14.52	b	0.41	a	0.58	a	120.18	b	53.68	a	12.90	b
16	PH18602	14.87	b	0.44	a	0.69	a	120.91	b	52.14	a	14.99	b
6	PH18202	20.86	d	1.60	b	0.63	a	124.92	d	51.83	a	13.16	b
4	PH18103	17.22	c	0.57	a	0.46	a	122.84	c	50.90	a	16.31	c
10	PH18401	19.17	c	1.84	b	0.37	a	124.98	d	43.07	b	19.63	c
5	PH18201	22.74	d	1.39	b	0.77	a	122.77	c	42.48	b	13.64	b

*means in a column followed by same letter are similar accordingly to Skott-Knott test (P<0.05).

To the variable White Belly, most genotypes showed excellent results, with very low incidence of this trait, differing from 0.14% to 0.61%, except for lines PH18401, PH18201 and PH18202. According to Xi et al. (2016) notable differences were detected between chalky grain with white-belly and translucent grains in chemical constituents, with chalky grains having lower levels of starch, protein, amino acids and low contents others micronutrients, another important reason for selecting whole and translucent grains in rice breeding.

For the variable Chalky Area, PH18102 and PH18302 lines stood out, being superior to the other breeding lines as well as to all control treatments, with 11.05% and 8.94%, respectively. It is important to emphasize that both lines have as parent to genotype BRS Pampa, a Brazilian cultivar of irrigated rice with high productivity, excellence in quality grain and low incidence of chalky area (Magalhães Jr. et al., 2012).

The line PH18302 was the genotype with the best grain translucency or vitreous whiteness (VW), with a constant of 117.61, differing from the other genotypes of this study. Finally, for the whole and broken grains variables, we emphasize the PH18102, PH18502 and PH18301 lines, which even not differing from the control treatments, are characterized by the high averages, above 59.97% for Whole Grains and below 8.30% for Broken Grains, with exceptional milling yields.

Conclusions

The results of this work indicate that the selection carried out was of great efficiency in the development of superior genotypes, especially regarding the physical attributes of grain quality.

The presented lines have potential and can be selected, after some generations advances, to compose the evaluations in other Embrapa yield tests, such as regional test (ER) and Cultivation and Use Value (VCU), with a possibility of release as new cultivars, as well as an increase in the program's workbench.

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Sensorial Analysis applied to rice in Italy

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Italy is the main rice growing country in Europe with about half of the total cultivated area. Italy is growing rice since the 15th century. After its introduction the Italian producers were able to adapt the production to their taste developing, mainly in the past century, the "risotto" rice varieties which differ from all other existing ones and soon become famous worldwide. Nowadays the number of rice varieties registered in the National Catalogue is 229. Only few of them are known by the consumers but many new local brands are developing every year and enter the market creating attention to new varieties, specific growing techniques, different milling processes and so on.

Rice is mainly grown in flooded fields but drill seeding in dry fields is growing since its introduction in the 70s and is now covering about 40% of the surface. Italian rice fields are allocated close to the Alps in Piedmont Region as well as close to the seaside in Sardinia Region with quite different weather conditions. Italian millers are using different polishing systems thanks to Italian, German or Japanese equipment. Storing of paddy rice occurs in metal, wooden, cement bins at conventional conditions or under cold treatment or carbon dioxide treatment. Usually rice is processed and consumed within one year from field harvesting but aging up to 7 years is now available.

Each of these factors (location, growing technique, milling system, storing method, etc.) might lead to a different quality of the final product.

Acquaverderiso developed a method of sensorial analysis applied to rice with the aim to create an objective tool to evaluate the quality and recognize the difference of the several rice varieties and rice products in the market. Panel test have been organized and interesting results gave confidence to future developments of the approach.

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Sensorial Analysis applied to Italian rice

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Introduction

Italy is the main rice growing country in Europe with about half of the total cultivated area. Italy is growing rice since the 15th century. After its introduction the Italian producers were able to adapt the production to their taste developing the risotto rice varieties. The number of rice varieties registered in the National Catalogue is 228 while the grown ones are 146. Only few of them are known by the consumers. Rice is mainly grown in water flooded fields but drill seeding sytems is growing and is covering about 40% of the surface. Italian rice fields are allocated close to the Alps in Piedmont Region as well as close to the seaside in Sardinia Region. Italian millers are using different polishing systems using Italian, German or Japanese technology. Storing of paddy rice occurs in metal, wooden, cement bins at room, cold or oxygen-free conditions. Usually rice is processed and consumed within one year from field harvesting but rice aged up to 7 years is now available in the market.
Each of these factors (location, growing technique, milling system, storing method, aging, etc.) lead to a different quality of the final product.

Objective

The aim of this work is to set a list of descriptors that can be used in a QDA (Quantitative Descriptive Analysis) of Italian rice.

Material and Methods

Samples of Italian risotto rice of the varieties (Carnaroli, Arborio, S.Andrea) were used. The tests were conducted with the panel group trained by Acquaverderiso in collaboration with SISS (Società Italiana Scienze Sensoriali, Firenze, Italy). A specific procedure was followed during the prearation of the test: the vacuum-sealed rice samples is open just before the test, a small quantity of grains (about 10 grams) are allocated on white&black tray for visual examination and in a glass for olfactory examination. In a separated room part of the sample is boiled in abundant water: 1/4 rice/water weight ratio. The boiled rice is examinated in ceramica tea cup covered with a metal lid.

Results

A set of 9 macro-descriptors is proposed:
1. Visual examination of raw rice
2. Tactile examination of raw rice
3. Olfactory test of raw rice
4. Olfactory test of boiled rice
5. Tasting of boiled rice
6. Visual examination of boiled rice
7. Visual examamination of the grain core of boiled rice
8. Firmess evaluation of cooked rice grain
9. Tasting examination after 10 minutes

The order of the macro-descriptors was chosen in the way for the panelist to have the maximum efficacy during the test, calculated in 30 minutes per sample. In raw rice the visual examination was positioned first, while in cooked rice the olfactory examination was positioned first to avoid aroma lost in the environment.
The firmness of the grain after cooking is considered essential in Italy in the same way the Italian like pasta “al dente”.

Conclusions

A set of 43 micro-descriptors was built. They seems to capture all the relevant sensorial traits of the Italian rice and can be used for QDA tests.

Micro-descriptor #	Macro-descriptor #	Description
1	1	Absence of visual defects (black spots, chalkiness, green grain, broken grain, others)
2	1	Correspondence to the cultivar
3	1	Uniformity of grains (if all have the same size and are uniform)
4	1	Colour match (depending on the cultivar and the processing)
5	1	Attractiveness (hedonic evaluation)
6	2	Absence of defects (dustiness, added oils, others)
7	2	Attractiveness (hedonic evaluation)
8	3	Olfactory intensity (how much is perceived)
9	3	Olfactory complexity (how many different scents are perceived)
10	3	Olfactory persistence (how many seconds the perfumes / smells remain fixed)
11	3	Aromaticity (primary of the cultivar)
12	3	Aromaticity (secondary, due to processing)
13	3	Olfactory quality (evaluation of positive characteristics)
14	3	Attractiveness (hedonic evaluation)
15	4	Olfactory intensity (how much is perceived)
16	4	Olfactory complexity (how many different scents are perceived)
17	4	Olfactory persistence (how many seconds the perfumes / smells remain fixed)
18	4	Aromaticity (primary of the cultivar)
19	4	Aromaticity (secondary for processing)
20	4	Olfactory quality (evaluation of positive characteristics)
21	4	Attractiveness (hedonic evaluation)
22	5	Texture of grains (hardness)
23	5	Absence of stickiness of granules (resistance to detachment of molars)
24	5	Sweet (starch based)
25	5	Absence of bitter
26	5	Absence of acid
27	5	Absence of metallic (electrolytic sensation)
28	5	Umami
29	5	Aromaticity (primary of the cultivar)
30	5	Aromaticity (secondary, due to processing)
31	5	Retro-gustative persistence (how many seconds the aromas remain fixed)
32	5	Taste quality (evaluation of positive characteristics)
33	5	Appetability (hedonic evaluation)
34	6	Increase in the volume of the grains (stretching, enlargement in cooking)
35	6	Uniformity of the grains (if all have been modified evenly)
36	6	Absence of stickiness of grains (grains remain separated)
37	6	Attractiveness (hedonic evaluation)
38	7	Absence of gelatinization of the grain
39	8	Texture of grains (hardness)
40	8	Absence of stickiness of granules (resistance to detachment of molars)
41	8	Firmness (cooking quality)
42	9	Absence of variation of the gustative characteristics of cooked rice
43	9	Appetability (hedonic evaluation)

For each descriptor a mark from 0 (absence) to 9 (fully present) is given

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Rice variety in Italy: evolution and trends

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In Europe Italy is the main rice growing country and the main country developing new rice varieties. In 1997 the number of varieties registered in the National Catalogue was 114. It moved to 229 in 2019 with an average of 5.2 new varieties every year.

The evolution of rice varieties followed the changes in the market requests. The traditional market changed quickly in the last decades. Farmers are looking for more efficient rice growing techniques while consumers are more and more exposed to international markets, new cooking styles, new ingredients, different habits and tastes.

In 1988 the first long B grain variety was developed in Italy, in 1995 the first aromatic rice, in 1997 the first black rice. The genetic resistance to chemicals was introduced in Italy 2006 with the first imi-tolerant rice. In 2012 the first hybrid rice was grown, in 2013 the first red rice was allowed in the National Catalogue. In 2019 the first ACC-asi resistant variety was introduced.

In 2017 a national law changed the way of labelling the rice sold in Italy introducing the concept of "classification". Each rice variety sold in Italy should be classified, in either the case that the variety has been registered in Italy or abroad. In some case the variety is not registered in any European Catalogue but only protected at CPVO (Community Plant Variety Office).

Nowadays in Italy the total number of classified varieties is 236, comprehensive of 37 varieties with round grain, 31 with medium grain, 25 with long A grain, 60 with long B grain. The traditional varieties belong to 6 groups: 8 varieties with Arborio grain type, 9 with Carnaroli grain type, 12 with Baldo-Roma grain type., 1 with Vialone Nano, 2 with S.Andrea type and 51 with Ribe type.

The poster contains detailed information about the evolution and trends of the varieties in the Italian rice market.

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Rice variety in Italy: evolution and trends

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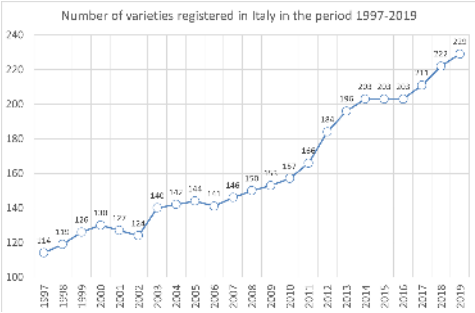
Introduction

In Europe Italy is the main rice growing country and the main country developing new rice varieties. In 1997 the number of varieties registered in the National Catalogue was 114. It moved to 229 in 2019 with an average of 5.2 new varieties every year.



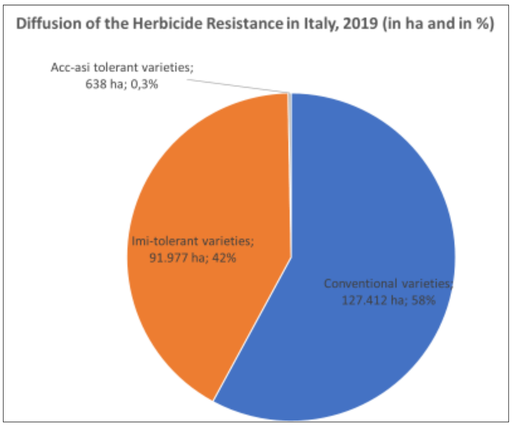
The evolution of rice varieties followed the changes in the market requests. The traditional market changed quickly in the last decades. Farmers are looking for more efficient rice growing techniques while consumers are more and more exposed to interna-tional markets, new cooking styles, new ingredients, different habits and tastes.

Objective

In this poster the evolution and trends of the varieties in the Italian rice market are presented.

Results

In 1994 the first semidwarf long B variety (Thaibonnet) was introduced in Italy while in 1995 the first aromatic rice (Gange) and in 1997 the first black rice (Venere). The genetic resistance to chemicals was introduced in Italy in 2006 with the first imi-tolerant rice (Libero). In 2008 the first variety (Yume) specifically for sushi was registered. 2012 the first hybrid rice (CLXL745) was grown, in 2013 the first red rice was allowed in the National Catalogue (Ermes). In 2019 the first ACC-asi resistant variety (PVL024) was introduced.



ID	VARIETY	Surface in Ha	Surface in %	% cumul
1	SELENIO	16.221	7,4%	7,4%
2	MARE CL	14.931	6,8%	14%
3	SOLE CL	14.345	6,5%	21%
4	LUNA CL	14.007	6,4%	27%
5	VOLANO	12.607	5,7%	33%
6	CENTAURO	10.887	4,9%	38%
7	CL 26	9.953	4,5%	42%
8	CAMMEO	8.461	3,8%	46%
9	CL 28	8.108	3,7%	50%
10	BARONE CL	7.894	3,6%	53%
11	CARNAROLI	7.805	3,5%	57%
12	GLADIO	6.172	2,8%	60%
13	TERRA CL	5.727	2,6%	62%
14	CARAVAGGIO	5.603	2,5%	65%
15	RONALDO	5.348	2,4%	67%
16	SIRIO CL	4.936	2,2%	70%
17	DARDO	4.624	2,1%	72%
18	TELEMACO	3.710	1,7%	73%
19	CL 388	3.551	1,6%	75%
20	VIALONE NANO	3.485	1,6%	77%
21	LEONARDO	2.918	1,3%	78%
22	S.ANDREA	2.633	1,2%	79%
23	GLORIA	2.512	1,1%	80%
	All the rest	43.591	19,8%	100%
	Total	220.027		

Nel 2019 a total of 166 varieties were grown in Italy. The 80% of the surface was grown with 23 varieties while 9 covered 50% of the surface and just 5 covered one third of it. The most diffuse grain type is the "risotto" long A type, while the least grown is the medium grain type. White non-aromatic is the common Italian rice but aromatic, black and red are becoming popular.

Grain Type	Surface in Ha	Surface in %	% IMI-tol.
Round	53.945	25%	38%
Medium	8.044	4%	2%
Long A for risotto	66.264	30%	20%
Long A for parboiled	38.812	18%	42%
Long B	52.962	24%	79%

Grain type	Surface in Ha
White conventional rice	217.963
White aromatic rice	506
Black rice	1.122
Red rice	436
Total	220.027

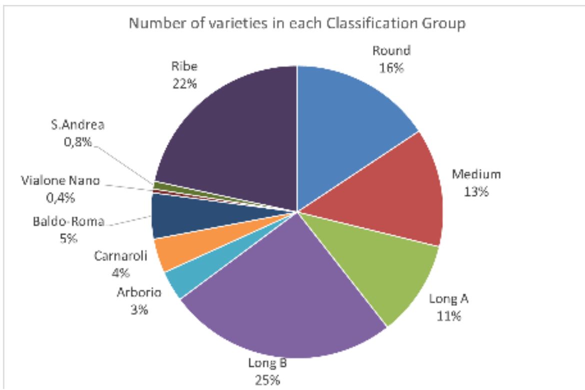
Classification of rice in Italy

In 2017 a national law changed the way of labelling the rice sold in Italy introducing the concept of "classification". Each rice variety sold in Italy should be classified, in either the case that the variety has been registered in Italy or abroad. In some cases the variety is not registered in any European Catalogue but only protected at CPVO (Community Plant Variety Office).

The classification is linked to 5 parameters of the white rice: length, width, length/width ratio, pearl, hardness. The varieties that fit the classification can enter one of the six "traditional Italian denomination", and will be sold mandatory with one the following names: Arborio, Carnaroli, Baldo or Roma, Vialone Nano, S.Andrea and Ribe. The other rice varieties can be sold as round, medium, long A and long B rice and voluntary with the variety name. If the pericarp is coloured and the grain is aromatic, it is obligatory introduce this information in the denomination on the label.

N.	Arborio	Carnaroli	Baldo / Roma	Vialone Nano	S.Andrea	Ribe		
1	ALERAMO	CARAVAGGIO	BACCO	VIALONE NANO	ALLEGRO	AGAVE	EUROPA	RG201
2	ARBORIO	CARNAROLI	BALDO		S.ANDREA	ANTARES	EUROSIS	RG202
3	CL388	CARNAVAL	BARONE CL			ARCHIMEDE	FENICE	RG203
4	CL510	CARNISE	BIANCA			ARIETE	FENOMENO	RIBALDO
5	GENERALE	CARNISE PRECOCE	CAMMEO			AUGUSTO	LEONARDO	RIBE
6	TELEMACO	KARNAK	CASANOVA			BRAVO	LINCE	RODEO
7	VOLANO	KEOPE	ELBA			CATULLO	LOTO	ROMBO
8	VULCANO	LEONIDAS CL	FEDRA			CL A01	LUNA CL	RONALDO
9		POSEIDONE	GALILEO			CL31	LUXOR	SAMURAI
10			NEVE			CL33	MECO	SCIROCCO
11			PROTEO			CL35	MERIDIO	SISR215
12			ROMA			CRESO	NEMBO	TEJO
13						DANTE	NEMESI CL	TETI
14						DARDO	ONICE	TIBERIO
15						DELFINO	OPALE	UNICO
16						DRAGO	PRESTO	VALENTE
17						ERCOLE	PUMA	VASCO

Nowadays in Italy the total number of classified varieties is 236, comprehensive of 37 varieties with round grain, 31 with medium grain, 25 with long A grain, 60 with long B grain. The traditional varieties belong to 6 groups: 8 varieties with Arborio grain type, 9 with Carnaroli grain type, 12 with Baldo-Roma grain type., 1 with Vialone Nano, 2 with S.Andrea type and 51 with Ribe type.



Conclusions

Rice growing is in strong evolution in Italy, not regarding the surface that is quite stable around 220,000 hectares since decades but regarding the varieties offered to the market.

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Genetic Progress of Irrigated Rice Breeding in Southern Brazil

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Abstract

Irrigated rice (*Oryza sativa* L.) is a staple crop in Brazil, and the state of Rio Grande do Sul, located in the southernmost part of the Country, accounts for more than 70% of the national production. The Brazilian Agricultural Research Corporation (Embrapa) is focused on rice breeding, aiming to develop cultivars with increased grain yield and improved sustainability. The aim of the study was to estimate the genetic progress along 45 yr of the irrigated rice breeding program of Embrapa in Southern Brazil (1972 - 2016), by means of a comparative analysis of cultivars in the same environment and by meta-analysis of line yield assays. The estimates resulted from a meta-analysis of 455 genotypes in 145 trials of regional line yield and value for cultivation and use of 44 agricultural crop seasons, and by comparing cultivars obtained by evaluating 25 cultivars in 10 agricultural cropping seasons. Genetic gains were evaluated for grain yield, plant height, and days to flowering. The cultivars released by the breeding program were also evaluated for important agronomic traits. The estimates determined a genetic progress for grain yield via meta-analysis and via comparison of cultivars of 0.62 (37.91 kg yr^{-1}) and 0.73% (47.78 kg yr^{-1}), respectively. It was also verified that during the period there was reduction in plant height and days to flowering. Three distinct historical phases defined changes in research focus and genetic gains: (i) 1972 - 1983, before the rice Green Revolution; (ii) 1983 - 2000, after the rice Green Revolution; and (iii) 2000 - 2016, selection intensification for industrial grain quality attributes. Other relevant genetic aspects, selection strategies, and phases of the breeding program were discussed. Over this 45-year period of research, Embrapa's genetic breeding program launched 25 temperate irrigated rice cultivars, with an average of approximately 1 new cultivar every two years of work. Included in this list, there are the cultivars BR IRGA 409 and BR IRGA 410, launched in 1979 and 1980, respectively, considered as responsible for the "green revolution" of farming in Brazil, due to the new architecture of semi-dwarf plants that reflected in increased crop grain yield. Currently, the highlight is the cultivar BRS Pampa, considered as premium rice by the industry for its quality of long and fine grain, and BRS Pampeira, which has the highest yielding cultivar among the ones developed by the breeding program, with grain yields superior to 12 t ha^{-1}.

Keywords: Embrapa; breeding program; temperate rice.

❺ *Precision agriculture*

Applying geotechnologies for grain yield intensification and diversification In Uruguay

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ABSTRACT

Land-leveling is used to correct soil surface irregularities to improve surface drainage and irrigation and make the area more manageable for an array of agricultural activities. Recently, technology using the Global Navigation Satellite System (GNSS) has been used to carry out projects with varying slope, called land-forming. The main goal of this work was to evaluate the land forming for irrigation (LFI) model in two fields located in Treinta y Tres – Uruguay, a field of 12.6 hectares cultivated with rice and another of 11.8 hectares with soybean. Each field was divided in half, comparing LFI with traditional management. In half of the area where soybean will be grown, the furrow Irrigation system was implemented, and flowmeters where installed to measure water consumption. In both areas soil samples were taken before and after the land forming, in order to verify the changes that occurred in the cutting and fill areas after the LFI model has been executed. Other parameters being measured are apparent electrical conductivity of the soil, moisture and penetration resistance in both areas before and after the LFI model. To measure productivity a combine harvester equipped with a grain yield sensor will be used. statistical analyses will be used to correlate the dependent and independent variables.

Key words: land leveling, irrigation, *GNSS*, rice, soybean.

Applying geotechnologies for grain yield intensification and diversification In Uruguay

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Introduction

The lowlands of the Mirim lagoon hydrographic basin, both on the Brazilian and the Uruguayan side, are predominantly flat and feature relatively shallow topsoil with high bulk densities (Lima et al. 2009), low hydraulic conductivities, and impermeable subsurface soils. The poor natural drainage is a key characteristic of this lowland agroecosystem (Parfitt et al. 2017) that has made it favorable for rice production for more than a century (Theisen 2017). Thus, this environment has favored the cultivation of irrigated rice in rotation with pasture as an agricultural activity, but in recent years soy has been introduced as an alternative for crop rotation, income generation and also a way of intensifying agricultural crops in this productive system.

Land-leveling is used to correct soil surface irregularities to improve surface drainage and irrigation and make the area more manageable for an array of agricultural activities. Recently, technology using the Global Navigation Satellite System (GNSS) has been used to carry out projects with varying slope, called land-forming. Land forming for irrigation (LFI) model can improve water management in rice and also allows the furrow irrigation in soybeans. The apparent electrical conductivity of the soil (Eca), moisture and penetration resistance can be used to determine management zones in the fields, with the intention of reducing the number of samples, without compromising the quality of the data.

Objective

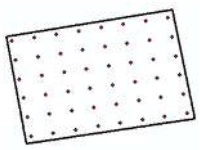
The main goal of this work was develop a sustainable intensification of two fields of the Laguna Merin basin through the crop rotation, using geotechnology tools for water management.

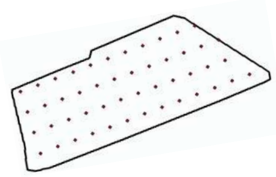
Specific objectives:

- Evaluate crop productivity in areas with and without LFI model.
- Evaluate crop productivity in cut/fill areas.
- Evaluate water consumption in irrigated rice and soybean crops.
- Determine the spatial variability of the chemical and physical attributes of the soil, in both areas, with and without LFI model.
- Make a statistical analyses to correlate apparent electrical conductivity of the soil, moisture and penetration resistance and productivity in both areas before and after the LFI model.
- Make a partial economic analysis of the use of precision agriculture and LFI model.

Material and Methods

To achieve the proposed objective, an experiment is carried out at the Paso de la Laguna Experimental Unit (33 ° 16 'S 54 ° 10' W), belonging to the National Agricultural Research Institute (INIA-Uruguay). Two fields located in Treinta y Tres – Uruguay, a field of 12.6 hectares cultivated with rice and another of 11.8 hectares with soybean.



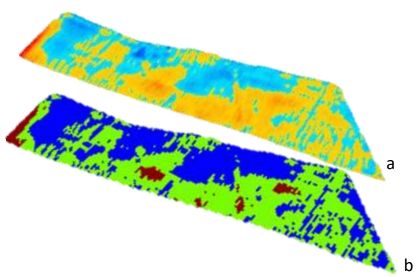


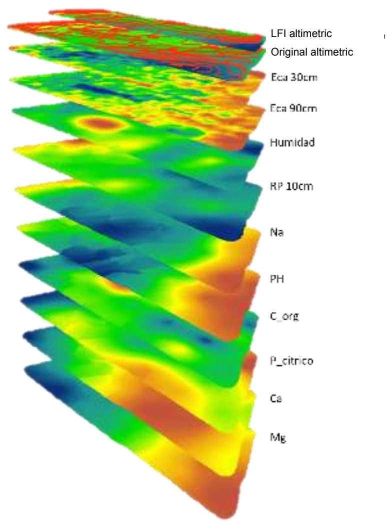
Each field was divided in half, comparing LFI with traditional management. In half of the area where soybean will be grown, the furrow Irrigation system was implemented, and flowmeters where installed to measure water consumption. In both areas soil samples were taken before and after the land forming, in order to verify the changes that occurred in the cutting and fill areas after the LFI model has been executed.

Other parameters being measured are apparent electrical conductivity of the soil, moisture and penetration resistance in both areas before and after the LFI model. To measure productivity a combine harvester equipped with a grain yield sensor will be used. Statistical analyses will be used to correlate the dependent and independent variables.

Results

As preliminary results, the altimetric maps with surface contours before and after the LFI model be applied, maps of Eca, humidity, penetration resistance (RP), and chemical soil attributes are showing (right). And the cut an fill map (a), and cutting area above 5 cm are showing below (b).





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PlanejArroz: Software for irrigated rice management planning and yield estimation

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ABSTRACT

Despite the high average yield of irrigated rice in the state of Rio Grande do Sul (above 7 t ha $^{-1}$), it is believed that this yield may be even higher if management practices are carried out according to the plant development stages - PDS. The problem is that the PDS, and especially the panicle differentiation (R1), is variable because it is temperature dependent. For this reason, is preferable to use the method of degree-days (DD) or thermal units instead of the number of days of the calendar. On the other hand, process simulation models such as SimulArroz, for example, are tools that can be used to estimate rice grain yield at different sowing periods and producing regions. The objective of this article was to show the fundamentals and the use of the software PlanejArroz to estimate the date of occurrence of six PDS, aiming the crop management, as well as to estimate the grain yield in the rice producing municipalities of the State. The software uses historical series (30-year) of daily average air temperature (Tm) data to calculate the average occurrence date of six PDS and Tm of the crop season to calculate deviations between average and crop season PDS. Similarly, by using the SimulArroz model, the average historical grain yield, the grain yield of the crop season and the deviations between both are estimated. The article provides examples of data generated by PlanejArroz for both phenology, aiming crop management, and grain yield, expressed in tables and maps. It is concluded that PlanejArroz is a tool that can help the rice farmers to perform the management practices at the most appropriate times and to estimate the expected grain yield for the established crop conditions.

Key words: degree-days, phenology, crop model.

1. Introduction

The average yield of irrigated rice in the state of Rio Grande do Sul, the largest national rice producer, is relatively high (above 7 t ha^{-1}). However, it is believed that the yield may be even higher if management practices are performed at the most appropriate time, considering the plant development stages – PDS, as recommended by Sosbai (2018).

The problem is that PDS, and especially panicle differentiation (PD or stage R1), is variable because it is temperature dependent (STANSEL, 1975). Therefore, it is preferable to express the stage R1 and the other PDS in days, but estimated by accumulated degree-days (ADD), or thermal units, rather than the number of calendar days (STRECK et al., 2006; STEINMETZ et al., 2010).

Based on this principle, Steinmetz et al. (2015) developed the software GD Arroz in the Web version (http://agromet.cpact.embrapa.br) and, later, the App for the Android platform (Google Play; GD Arroz).

In addition to management, the sowing time, as well as the cultivar cycle, can also greatly affect the yield of irrigated rice (MENEZES et al., 2003; MARIOT et al., 2005; STEINMETZ et al., 2009).

The process simulation models such as SimulArroz, are tools that can be used to estimate rice grain yield at different sowing times and producing regions (ROSA et al., 2015; RIBAS et al., 2016).
The objective of this article was to show the fundamentals and the use of the software PlanejArroz to estimate the date of occurrence of six plant development stages, aiming the crop management, as well as to estimate the grain yield for the established crop conditions.

2. Material and Methods

2.1. Fundamentals of the software

2.1.1. Management (Phenology)

To estimate the “average” date for each of the six PDS the software uses a 30-year historical series (1987-2016) (POWER / NASA, 2018) of daily maximum air temperatures (Tx) and minimum air temperatures (Tn), while for the "crop season" the data of Tx and Tn are those received daily from the National Institute of Meteorology (INMET). The daily average temperature (Tm) is obtained by the arithmetic average between Tx and Tn. The equation for calculating degree-days was that of Slaton et al. (1996), using the base temperature of 11 ° C (Infeld et al., 1998).

For the first three cultivars (IRGA 424 RI, Guri Inta CL and Puitá Inta CL), which were the most sown in previous years, it was used the accumulated degree-days (ADD) based on experimental data of four agricultural crop seasons (data obtained by the first author, unpublished). For the other 38 cultivars it was used the mean ADD of the subgroups to which they belong to (STEINMETZ et al., 2015).

The maps were elaborated in a geographic information system from the interpolation of the relief model of the state of Rio Grande do Sul with equation obtained for each ten-day period (TDP) by multiple regression between the independent variables, altitude, latitude and longitude, and the number of days after emergence' for each of the six stages, as a dependent variable, in the twenty-two locations where this parameter was estimated by the degree-day method.

As a result of the combination of the three most seeded cultivars and seven cultivar maturity groups, for eleven ten-day periods (from September 1st to December 2nd), and from the six phenological stages, 660 maps representing the classes of 'number of days after emergency' were produced.

2.1.2. Grain yield

Grain yield for the three previously mentioned cultivars was estimated by the SimulArroz model (ROSA et al., 2015). The TDP average yields were established from the first TDP of September until the second TDP of December, denominated “**Average (30 years) – Média (30 anos)**”, utilized the same climate database used for phenology. The grain yield of the “**Crop Season – Safra**” was estimated using the daily data received from INMET. The “**Average Deviation – Desvio da Média**” represents the difference between the average data and those of the current crop season. The TDP maps, representing the average yield of thirty years were interpolated, also in geographic information system, using the ordinary kriging method.

2.2. Input information

2.2.1. Management (Phenology)

If the user's “**Interest - Interesse**” is for “**Management - Manejo**”, the next step is to indicate the “**Municipality - Município**” and the “**Cultivar - Cultivar**” to be used. Next, the stage of interest is defined among the six available: V4-Collar formation on Leaf 4; R1-Panicle differentiation; R2-Flag leaf collar formation; R4-Anthesis; R8-Single grain maturity; R9-Complete panicle maturity. Then, the “**Date of emergency – Data de emergência**” is defined, which corresponds to 50% of seedlings emerged in the field. Finally, the option is “**Consultation by municipality – Consulta por município**” or “**Consultation by map – Consulta por mapa**”.

2.2.2. Grain yield

If the "**Interest - Interesse**" is for "**Grain yield - Produtividade**", the next step is to indicate the "**Municipality - Município**", the "**Cultivar - Cultivar**" and the "**Date of Emergency – Data de emergência**". Finally, the option is "**Consultation by municipality – Consulta por município**" or "**Consultation by map – Consulta por mapa**".

The Web version of the software can be accessed at: http://agromet.cpact.embrapa.br and select "**PlanejArroz**". The App (for Android) can be downloaded for free from Google Play.

3. Results and Discussion

3.1. Outputs of the software (Phenology)

3.1.1. Consultation by municipality

To exemplify, the following variables were selected: Municipality: Santa Maria; Cultivar: IRGA 424 RI; Stage: R1 - Panicle differentiation; Date of emergency: 5/10. After filling in the fields indicated, select "**Consultation by municipality – Consulta por município**".

In "**Average (30 years) – Média (30 anos)",** the field "**No. days (E-R1) – Nº dias (E-R1)**" indicates that this cultivar, on average of 30 years of daily Tm data, required 69 days after seedling emergency to reach the R1 stage (Figure 1 – at left).

The "**Date (R1) – Data (R1)**" field indicates that 69 days after emergency (5/10) corresponds to 13/12 (Figure 1 – at left). This indicates the average date on which stage R1 occurred in these thirty years.

In "**Crop season - Safra**", the field "**No. days (E-R1) - Nº dias (E-R1)**" was 67 days and "**Date (R1) - Data (R1)**" was 11/12, making the "**Deviation (days) - Desvio (dias)**" less 2 days (Figure 1 – at left). This means that in the period from 5/10 (seedling emergency) until reaching the ADD necessary for the occurrence of stage R1 of the crop in question, ie 11/12, the average air temperature (Tm) was higher than the historical average Tm (30 years).

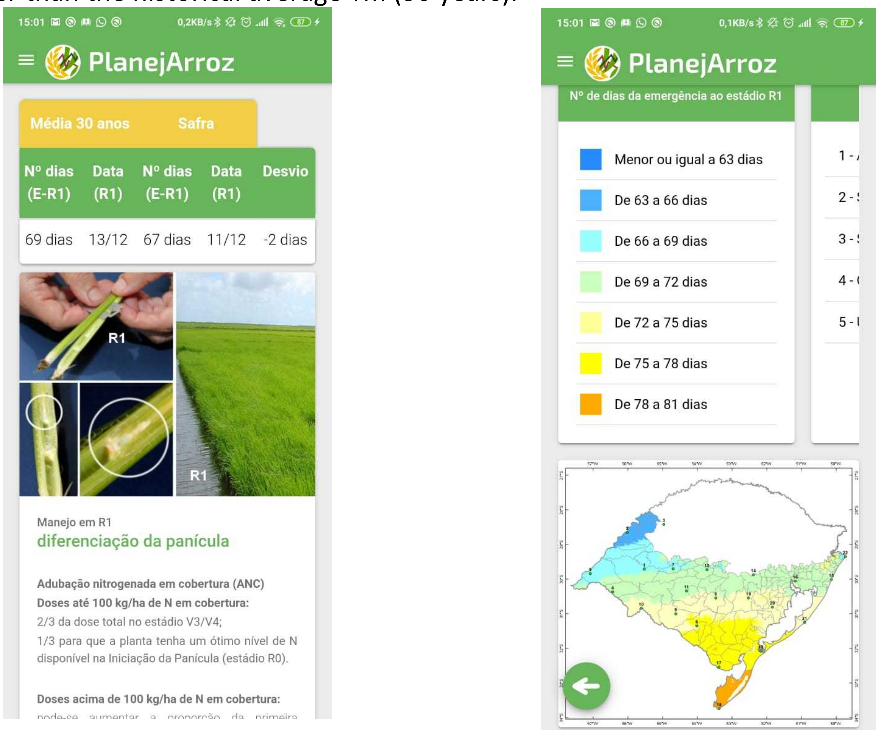

Figure 1. Software output for "Management - Manejo" (Consultation by location - at left) involving the data relative to the plant stage R1 for the period of 30 years (Média 30 anos), for the crop season (Safra), the deviation between them (Desvio), images of the R1 stage in the plant and in the field and management recommended by Sosbai (2018). Map indicating that in Santa Maria and other municipalities the period from seedling emergency to R1 is in the range of 69 to 72 days (Consultation by map - at right).

Below the output data one can see the illustrations for the stage R1, in the plant and in the field, and the management practices recommended by Sosbai (2018) to be used at this PDS (Figure 1 – at left). The same type of output is available for the other five plant stages.

3.1.2. Consultation by map

Another possibility offered by the software is to visualize, in the form of maps, the spatialization of the generated data (Figure 1 – at right). The map aims to indicate to the user not only the data of the selected municipality, but also for the surrounding ones.

3.2. Outputs (Grain yield)

3.2.1. Consultation by municipality

To exemplify the output related to the grain yield it will be utilized the same input variables used for phenology, ie: Municipality: Santa Maria; Cultivar: IRGA 424 RI; Date of emergency: 5/10. After filling in the fields indicated, select "**Consultation by Municipality**".

In "**Yield (Average 30 years) – Média (30 anos)**", a value of 10,707 kg/ha is obtained, while in "**Yield (Crop season) – Safra**" indicates 11,201 kg/ha, corresponding to a "**Deviation - Desvio**" of plus 494 kg/ha, corresponding to plus 4.6% (Figure 2 – at left). This indicates that the weather data used in the SimulArroz (Tx, Tn and solar radiation) of the crop season 2019/2020, until the day of the consultation (7/12/2019), were more favorable for crop yield than historical data (30 years).

3.2.2. Consultation by map

The map (Figure 2 – at right) indicates that for all municipalities that have the same color as Santa Maria, the estimated grain yield would be similar.

Figure 2. Software output for "Yield" involving average yield (30 years), yield for the crop season 2019/2020 and deviation (kg/ha and %) (Consultation by location - at left), and average yield for Santa Maria and other municipalities of the state of Rio Grande do Sul (Consultation by maps - at right).

Conclusions

The software PlanejArroz (available in Web and App for the Android platform) is a tool that can help the rice farmers to carry out management practices at the most appropriate times by estimating the date of occurrence of six plant development stages associated with these practices;

The PlanejArroz grain yield estimation can be useful either on planning to sow according to the best sowing period or for the yield forecast once the crop is already established.

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6 *Rice and its environment*

Arsenic concentration in grains of commercial rice varieties, under two irrigation systems. Argentina

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ABSTRACT

In Argentina about 200,000 hectares of rice are sowed whose production is mainly destined for export. In some areas of rice production in Argentina, high values of Arsenic (As) in grains are recorded. The objective of this work was to evaluate the effect of the interruption of irrigation on the concentration of total and inorganic As in different rice varieties.

For 4 years, field experiments were conducted in an area with high levels of As in grain recorded previously. Two irrigation management were evaluated: a) continuous flood irrigation b) interrupted irrigation in the vegetative stage. Five commercial varieties were tested. The total (As-t) and inorganic (As-i) arsenic content in whole grains (brown) and polished grains (white) was determined.

The rice grains yield was significantly affected by the variety and the year, but not by the irrigation system. On the other hand, the As concentration was affected by the year, the variety and the method of irrigation. No interaction between variation sources was observed. The varieties with the highest yield exceeded 11 t ha^{-1} and those with the lowest yield 6.5 t ha^{-1}. The concentration of total As in white grain was mostly above 0.30 mg kg^{-1}, which is a maximum limit of Mercosur. However, only 2 samples exceeded 0.20 mg kg^{-1}, the limit of inorganic As established by CODEX. Under the same conditions, some varieties showed twice As concentration en grain than others. Under irrigation with continuous flooding, the As-t in polished grain was 0.67 mg kg^{-1} and As-i 0.09 mg kg^{-1} on average. While the interruption of irrigation and drying of the soil in vegetative showed a significant reduction to 0.38 mg kg^{-1} As-t and 0.07 mg kg^{-1} As-i. With the choice of the appropriate variety and using interrupted irrigation it is possible to reduce the concentration of As in grains significantly.

Key words: contaminants, environment, healthy food, customs barriers.

1. Introduction

It has been observed that rice grain accumulates higher concentrations of As compared to other cereal crops. The flooded anaerobic conditions in rice cultivation facilitates As mobilization in the soil solution, mainly as AsIII, that is assimilated by rice roots. Microorganisms play a key role in As transformation through oxidation/reduction, and methylation/volatilization reactions, but transformation kinetics are poorly understood (Kumarathilaka et al., 2018). Alternate wetting and drying (AWD) irrigation can be used to promote oxic soil conditions and decrease arsenic (As) mobility and uptake into rice plants (Li et al., 2019). Other of the effective methods for reducing heavy metal accumulation in rice grains is selection and breeding of low grain-heavy metal accumulating cultivars (Khanam et al., 2020).

In Argentina, some 200,000 ha of rice are sown in a large production area in very heterogeneous environments. Some papers report As concentrations in argentinean rice, but only for the southern region (Farías et al., 2015). Recently, a complete survey of all rice production areas in Argentina has been presented (Oteiza et al., 2020). It has been reported that the production areas in the center/south of Corrientes and north of Entre Ríos have more than 50 % of the samples with total As values exceeding 0.30 mg kg^{-1}. The Codex Alimentarius has established a 0.20 mg kg^{-1} limit of inorganic As in polished rice grain, while the Argentine Food Code, in accordance with the Mercado Común del Sur (Mercosur), has set an advisory level of 0.30 mg kg^{-1} of total As.

Although in Argentina the proportion of rice grains with more than 0.20 mg kg^{-1} of inorganic As is less than 5 %; in areas with problems, the proportion is higher (Oteiza et al., 2020). Therefore, it is important to analyze management strategies to reduce the allocation of As in grains in these environments. The objective of this work was to evaluate the effect of irrigation management on the concentration of total and inorganic arsenic in rice grains of different commercial varieties.

2. Material and Methods

For four years (2015-2019), different rice commercial varieties were evaluated in producer fields within the area where high values of As in grains have been recorded. 1. FADO (double grain), 2. GUADIAGRAN (medium grain), 3. HISPAMAR (medium grain), 4. IRGA 424 (long fine grain), 5. GURÍ INTA (long fine grain).

The irrigation management alternatives evaluated were two: 1. “Continuously Flooded” (CF): flood irrigation from fourth leaf to maturity, 2. “Interrupted Flood” (IF): irrigation with flood from fourth leaf, drying of the soil during tillering and later re-flood from end of the tillering/panicle differentiation, until maturity. The design of the experiments was in divided plots, where the main plot corresponded to irrigation management, the sub-plots were the varieties. Each treatment included three randomly arranged repetitions.

Grain yield was evaluated by harvesting all 2x5 meter (10 m^2) plots with experimental harvester, correcting for humidity at 14%. The concentration of total arsenic (As-t) and inorganic arsenic (As-i) in white rice grains and in brown rice was also evaluated. Arsenic concentration analyzes were performed using ICP-MS for As-t and HG-AAS for As-i; they were carried out by Eurofins Global Control, Hamburg, Germany.

The sowing was done with regular machinery of the producer (20 cm between the lines). Densities of 170 kg ha^{-1} of seed were used in the long fine varieties and 200 kg ha^{-1} in the double or medium varieties. N-P-K fertilizer was not applied to the sowing so as not to alter the results and because the fields are good fertility in P and K. Then, Urea 70 kg ha^{-1} pre flood (4 leaves) and plus 70 kg ha^{-1} in panicle differentiation (re flood) were applied.

The 2015/16 and 2018/19 cycles were more rainy than normal and difficult the drying treatment. 2015/16 was particularly wet and cold, with lower yields. The 2017/18 cycle was very dry and with high radiation which allowed very high yields.

3. Results and Discussion

The rice grains yield was significantly affected by the variety and the year, but not by the irrigation system. On the other hand, the As concentration was affected by the year, the variety and the method of irrigation. No interaction between variation sources was observed (Table 1).

The “crop cycle” effect can be seen in Table 1. The 2015/16 campaign characterized by excess rainfall, cold and lower radiation, showed lower yields. On the other hand, quite the opposite, in 2017/18 very high yields were observed. The “crop cycle” effect was also significant on the concentration of arsenic in the grains. In the 2015/16 campaign, with a lower yield, the concentration of As in both whole grain and polished grain was significantly higher (Table 1).

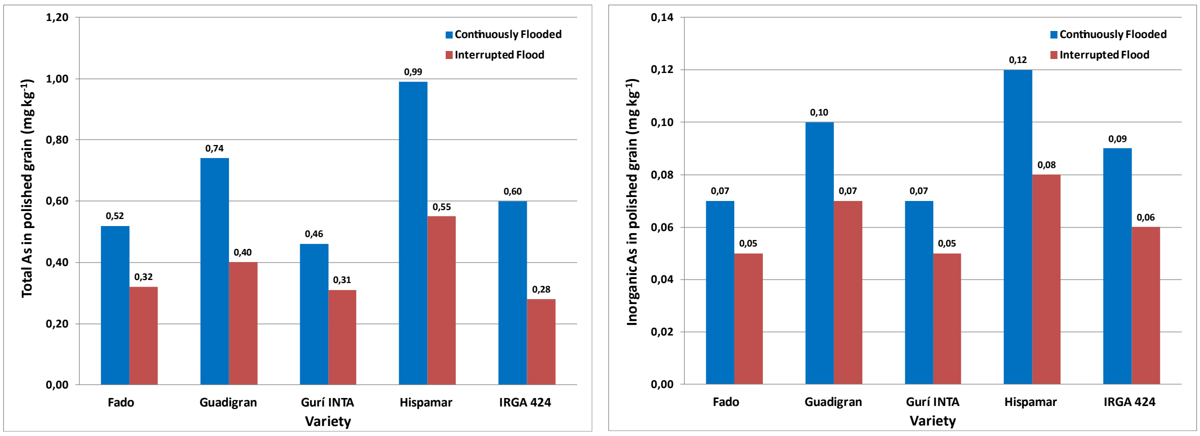
The "variety" effect was also very significant on the yield and concentration of As (Table 1). Guri INTA and IRGA 424 highlighted by the high performance and low concentration of As; followed closely by Fado. While Guadiagrán showed the lowest yield and an intermediate concentration of As, Hispamar variety was the one that presented the highest values of As.

The effect of irrigation management was very significant on the concentration of As in the grains, although it did not affect the rice yield for the average of the data. It is important to highlight here, that carrying out a field test with different varieties (which differ in their cycle) may present results that are affected by irrigation management, which was not appropriate for all cycles of the varieties evaluated. Therefore, a slight (not significant) reduction in the grain yields of some varieties was observed. It is relevant to visualize that with the irrigation management, similar yields of rice grain can be obtained, but with a significant and important reduction in the amount of total and inorganic As, both in whole grain and polished (Figure 1).

Table 1. Comparison test of means for the main effects.

Source of variation	Grain Yield kg ha^{-1}	As-i brown mg kg^{-1}	As-t brown mg kg^{-1}	As-i white mg kg^{-1}	As-t white mg kg^{-1}
Crop cycle					
2015-16	6455 a	0,16 c	0,89 b	0,12 b	0,77 b
2016-17	9007 c	0,12 b	0,48 a	0,07 a	0,43 a
2017-18	12218 d	0,11 b	0,53 a	0,06 a	0,43 a
2018-19	8077 b	0,09 a	0,56 a	0,06 a	0,54 a
Variety					
Fado	9239 c	0,10 a	0,50 a	0,06 a	0,42 a
Guadiagrán	6993 a	0,13 b	0,68 b	0,09 bc	0,57 b
Gurí INTA	11054 e	0,10 a	0,42 a	0,06 a	0,39 a
Hispamar	8415 b	0,15 b	0,87 c	0,10 b	0,77 c
IRGA 424	10475 d	0,11 a	0,51 a	0,08 ab	0,44 a
Irrigation					
Continuous Flood	9251 a	0,13 b	0,76 b	0,09 b	0,67 b
Interrupted Flood	9123 a	0,11 a	0,45 a	0,07 a	0,38 a

Means with a common letter are not significantly different (p <= 0.05). Test: LSD Fisher Alpha = 0.05.



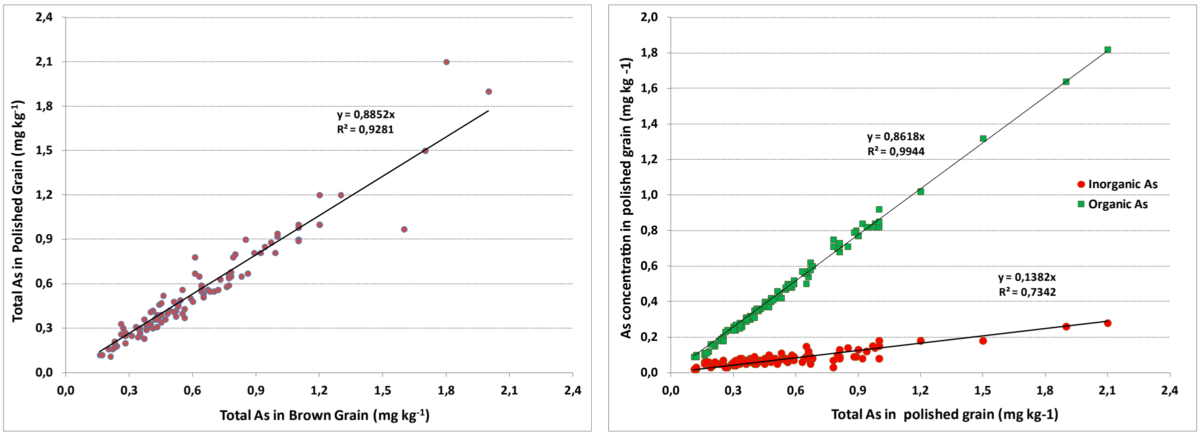
(a) (b)

Figure 1. Concentration of total (a) and inorganic (b) As in grains of polished rice, for the different varieties and the two irrigation methods evaluated.

The varieties of fine long grain rice (Guri INTA and IRGA 424) are the most sown in Argentina. They were characterized by high yield and relatively low concentration of As in grains (Table 1). Among the recently introduced medium or double grain varieties, Fado presented a good yield and low concentration of As. Hispamar was the variety with the highest concentration of As, significantly above the others with good yield. Guadiagrán was the cultivar of lower yield in the trials, this was possibly due to having a very short cycle and was more affected by the general management for longer cycle varieties in the trial. Guadiagrán presented an intermediate As concentration (Figure 1).

A very close relationship between the total As in polished and integral grain was observed. Polishing reduced the As concentration by 11.5% (Figure 2a). As it has been observed in previous reports (Farías et al., 2015; Oteiza et al., 2020), although high values were registered, arsenic is mostly found in methylated forms of low toxicity (Figure 2b). Very few samples exceeded the 0.20 mg kg^{-1} in As-i, limit set by CODEX.

The interruption of the flood led to a reduction of the total As in the order of 40 to 45%. This decrease was mainly due to a lower level of organic methylated forms (dimethyl arsenic: DMA) since inorganic arsenic was only reduced 18-20%. The concentrations of DMA in rice grain were higher under CF, compared to IF because microbial methylation in rhizosphere is favored under anoxic conditions, leading to more DMA uptake, compared to oxic conditions. In order to achieve a significant reduction in the concentration of As in the grain, it is necessary to perform a severe enough flood interruption (Li, et al 2019).



(a) (b)

Figure 2. Concentration of total As in brown and polished grain (a) and inorganic and organic As in grains of polished rice (b).

Conclusions

This work has been able to demonstrate that by selecting varieties and interrupting flood irrigation in the vegetative period it is possible to reduce the concentration of As in rice grains very significantly without affecting yields.

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Aquatic insects in rice fields from the East of Uruguay

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ABSTRACT

Uruguayan rice crop is mainly produced under irrigation, which generates a temporary semi-aquatic environment from tillering to pre-harvest. This condition may be favorable for the development of insects and other macroinvertebrates that depend on the aquatic environment. This differential feature, added to its location in wetland regions, presents the crop as a potential reservoir of biodiversity. Works on aquatic macroinvertebrates in Uruguay refer mainly to natural environments, but the studies in agroecosystems are scarce, without works on aquatic macroinvertebrates in rice crop in our country. This work is a first approach to the knowledge of insects and other aquatic macroinvertebrates from rice agroecosystem. Taxonomic groups composition may represent an approximation to the knowledge of water sources quality associated with rice production in eastern Uruguay. Sampling of aquatic macroinvertebrates was carried out in February 2015 in the localities of Julio María Sanz, El Tigre and General Enrique Martínez (Charqueada), in the department of Treinta y Tres. In each crop, macroinvertebrates were collected with a surber-type network at the entrance of water to the crop, the water outlet and a neighboring control area. Differences in the composition of morphospecies were found according to the location and source of water. The individuals of *Caenis* sp (Ephemeroptera: Caenidae) were associated with the water inlets, while the larvae of the diptera Syrphidae and Chironomidae (morphospecies 2) predominated in the water outlets. The highest richness and Shannon diversity indices were recorded in the location of El Tigre at the water outlet. Richness and Shannon diversity indices were higher than those recorded for similar crops in Costa Rica, Italy and Australia.

Key words: sustainability, biodiversity, conservation.

Aquatic insects in rice fields from the East of Uruguay

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Introduction

Uruguayan rice crop is mainly produced under irrigation, which generates a temporary semi-aquatic environment from tillering to pre-harvest. This condition may be favorable for the development of aquatic insects and other macroinvertebrates. This situation, and its location in wetland regions, presents the crop as a potential reservoir of biodiversity. Works on aquatic macroinvertebrates in Uruguay refer mainly to natural environments, but the studies in agroecosystems are scarce, without works on aquatic macroinvertebrates in rice crop in our country.

Objective

This work is a first approach to the knowledge of insects and other aquatic macroinvertebrates from rice agroecosystem in Uruguay.

Materials and Methods

-Sampling of aquatic macroinvertebrates with surber net.
-Uruguay, Treinta y Tres department.
-Localities: Julio María Sanz, El Tigre and General Enrique Martínez (Charqueada), february 2015 (Figure 1).
-Water sources: entrance, outlet and a neighboring control area (Figure 2). Three samples per water source per locality following (Rizo-Patrón et al., 2011).

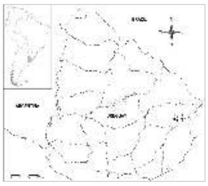


Figure 1. Sampling locations. 1: JM Sanz, 2: El Tigre, 3: Charqueada.

Figure 2. Water sources sampled A: entrance, B: outlet and C: control.

-Individuals counted and organized into functional groups following (Ramírez y Gutiérrez-Fonseca, 2014).
-Cumulative species curve was constructed (EstimateS 9.1.0, Collwell, 2013). Principal component analysis was done according water source (PAST 3.14, Hammer et al., 2001). Richness and Shannon diversity indices were calculated for each locality and water source (ANOVA and Tukey test).

Results

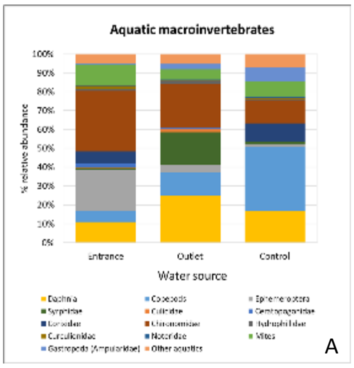
For the three localities sampled were registered 2851 individuals. Insect represented 43% of total individuals, while the rest of macroinvertebrates represented 57% (Table 1).

Table 1. Relative abundances of macroinvertebrates (no insects) collected with surber net in rice crop and its surroundings in Treinta y Tres, Uruguay (february 2015).

Class	Order	Family	Genus/morpho specie	Relative abundance (%)
Maxillopoda	Cyclopoida	Cyclopidae	*Copépodos*	22,50
Branchiopoda	Anomopoda	Daphniidae	*Daphnia*	18,12
Arachnida	Araneae	*Allocosinae, Lyniphiidae, Anyphaenidae*	unidentified juveniles	0,32
	Trombidiformes (subclass Acarina)	Hydrachnidae	*Hydrachna* y otros	8,00
Gastropoda (snails)	Caenogastropoda	Ampullariidae	*Pomacea* y otros	4,88
Oligochaeta	Tubificida	undetermined	unidentified earthworm	1,77
Malacostraca	Amphipoda	posibly Hyalellidae	posible *Hyalella* sp	1,35
Clitellata	Hirudinea	undetermined	unidentified leech	0,28

Within insects Ephemeroptera were more abundant in water entrance while Syrphidae larvae (Diptera) were more abundant in water outlet (Figure 2).
Cumulative species curve shows that are still species pending sampling. Richness estimators values were Chao 1=59.8%, Jacknife1= 66.4% and Bootstrap=74.4% estimating a total number of 48, 44 and 39 insect species, respectively.

Results



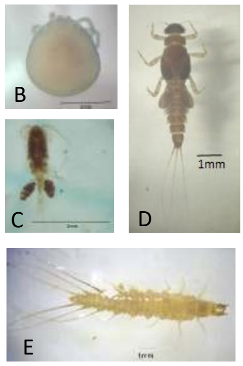


Figure 2. A: Relative abundances of aquatic macroinvertebrates collected with surber net according to water source (entrance, outlet, control), Treinta y Tres, Uruguay (entrance, outlet, control). B: mites (*Hydrachna*), C: copepods, D: Ephemeroptera larva (*Caenis*), E: Hydrophilidae larva (*Berosus*).

Principal Components Analysis comparing community composition showed that samples grouped according water source (Figure 3). *Caenis* individuals (Ephemeroptera) were associated to the water entrance, while Syrphidae and Chironomidae morphospecie 2 larvae (Diptera), where more abundant in water outlets.

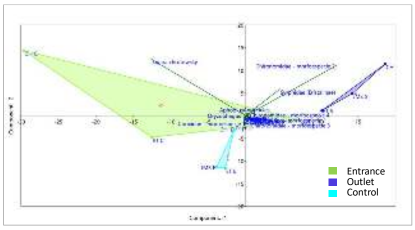


Figure 3. Principal component analysis (PCA) through Bray Curtis distances for each locality (ET: El Tigre, JMS: Julio María Sanz, CH: Charqueada) and water source (E: entrance, S: putlet, C: control), autovalues Axis 1: 57,74%, Axis 2: 21,51%.

The highest richness and Shannon diversity indices were recorded in the location of El Tigre at the water outlet (Table 2).

Table 2. Richness and Shannon diversity indices for insects in wáter samples according to water source and locality (Treinta y Tres, Uruguay, february 2015).

Diversity	El Tigre	J.M. Sanz	Charqueada
	Control		
Richness (S)	11,00±1,31a**B**	7,00±1,31a**AB**	7,33±1,31aA
Shannon_H	1,40±0,15a**A**	1,19±0,15aA	1,05±0,15aA
	Entrance		
Richness (S)	6,33±0,92a**A**	9,00±0,92a**B**	7,67±0,92aA
Shannon_H	1,55±0,12a**A**	1,54±0,12aA	1,64±0,12aA
	Outlet		
Richness (S)	13,33±0,67**bB**	4,67±0,67**aA**	5,33±0,67**a**A
Shannon_H	2,02±0,07**bB**	1,14±0,07**a**A	1,14±0,07**a**A

Different small letters within lines and big letters within column indicates significant differences through Tukey test (p<0.05).

Conclusions

Different taxonomic groups were associated to diferent water souces. Some groups like *Caenis* could be associated to good water quality, while others like Syrphidae are more associated to high levels of organic matter.

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Sustainability assessment tool applied in large scale, mechanized rice systems in Uruguay

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ABSTRACT

Sustainable intensification practices are designed to meet current and future food security needs while decreasing environmental impacts. Sustainability assessment of agriculture production systems should cover economic, social, environment and productivity issues. Uruguay export approximately 95% of his rice production and constantly is looking to add value to its production. Considering an objective evaluation, we propose to assess Uruguay rice production based on a tool that evaluates sustainability with a multidimensional approach. The Sustainable Rice Platform (SRP) which INIA is a member, is a multi-stakeholder program established in 2011. The SRP is co-convened by UN Environment and the International Rice Research Institute (IRRI) to promote resource efficiency and sustainability in trade flows, production and consumption operations, and supply chains in the global rice sector. However, up to now, most of the scientific work and applications of this tool have been conducted within the context of smallholder rice farming systems in Asia. We aim to apply and validate SRP Standards and Indicators to field data from large scale, mechanized rice systems in Uruguay.

Key words: sustainability, multicriteria analysis, Oryza *sativa,* SRP.

Sustainability assessment tool applied in large scale, mechanized rice systems in Uruguay

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Introduction

Sustainable intensification practices are designed to meet current and future food security needs while decreasing environmental impacts.

Sustainability assessment of agriculture production systems should cover economic, social, environment and productivity issues.

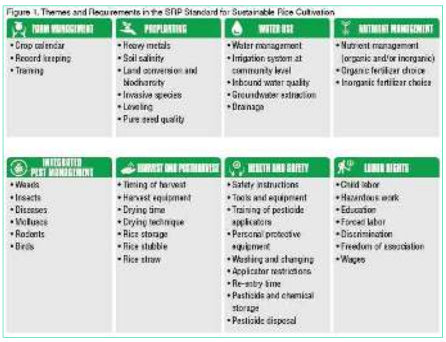
Uruguay export approximately 95% of his rice production and constantly is looking to add value to its production

Objective

The objective is to assess Uruguay rice production based on a tool that evaluates sustainability with a multidimensional approach.

Material and Methods

- The Sustainable Rice Platform (SRP) which INIA is a member, is a multi-stakeholder program established in 2011.
- The SRP is co-convened by UN Environment and the International Rice Research Institute (IRRI) to promote resource efficiency and sustainability in trade flows, production and consumption operations, and supply chains in the global rice sector.
- The SRP developed a set of instruments to evaluate rice production systems. One of them is based on a survey and its "The standard" and other one is the Performance Indicators.



1. Profitability: net income from rice
2. Labor productivity
3. Productivity: grain yield
4. Water productivity and quality
5. Nutrient use efficiency: N
6. Nutrient use efficiency: P
7. Biodiversity
8. Greenhouse gas emissions
9. Food safety
10. Worker health & safety
11. Child labor & youth engagement
12. Women empowerment

FIgure1. Requirements and themes in the Standard and Performance Indicators.

Figure 3. SRP Scoring Claims

Examples of Results using SRP standard and Performance Indicators

The figure below shows the summarized result of the standard. This is a simulated result based on assumptions. The tool shows the score obtained in the standard and shows how many thresholds failed and in which themes there are missed thresholds.

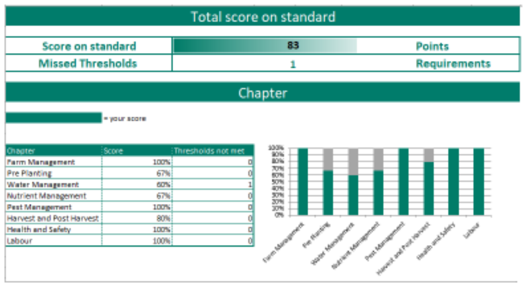


Figure 2. Summarized simulated result on the standard.

Table 1. Example of performance indicators in one season at farm level (n=670).

Performance indicator	Mean	SD	P(10)*	P(90)*
Grain Yield (kg ha^{-1})	8346	1717	6098	10269
NUE (kg kg^{-1})	112	37	70	153
PUE (kg kg^{-1})	483	165	295	683
# spary per season	3.3	0.91	2	4
Methane emissions (kg CH_4 ha^{-1})	180	17	159	200

NUE and PUE: nitrogen and phosphorous use efficiency (kg grain per kg of elemental nutrient).
SD: standard deviation; P(10): 10%percentile; P(90): 90%percentile. Grain yield at 14% moisture content.
*percentiles were made for each variable.

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http://www.sustainablerice.org/Resources/#srp-standard
http://www.sustainablerice.org/Resources/#performance-indicators

Acknowledgments

The authors gratefully acknowledge SAMAN's mill to provided field data to make a first exploratory assessment on SRP Performance indicators in Uruguay.

Rice Productivity and Resource Use Efficiencies in Uruguay

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ABSTRACT

Sustainable intensification implies equal emphasis on productivity and environmental goals. In global rice production, large negative environmental impacts are associated with low nitrogen use efficiency, high energy inputs, and high carbon footprint. Despite the need to balance the competing demands of increasing rice yield while reducing environmental costs, relatively few studies have used field-level farmer data to examine the implications of farmers managing for high yields versus maximum resource use efficiencies and sustainability outcomes. The objective of this study was to evaluate relationships and potential tradeoffs between yields and input use efficiencies using field-level records from 2012 to 2017, covering approximately 70,000 ha (40% of total rice area) for rice production in Uruguay. Results suggest it is challenging to simultaneously maximize yield and multiple resource use efficiencies (nitrogen, energy, carbon) at the farm-level. The impacts of maximizing performance of one indicator on others was indicator-specific. For example, farms that maximized energy use efficiency had fewer tradeoffs and more synergies with other indicators, whereas farms that maximized carbon footprint had less chance for optimizing across indicators. Importantly, there was room for improving resource use efficiencies at yields increased, but only up to a certain point for each indicator. Together these results suggest that maintaining high efficiencies at high yield levels is an inherent challenge that needs to be acknowledged in sustainable intensification efforts.

Key words: yield gap, sustainable intensification, resource use efficiency, field data

Effect of sowing date on four critical traits for temperate japonica rice cultivation in the last 10 years

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ABSTRACT

Rice production in temperate regions usually has a narrow window for crop establishment. Correct sowing date is crucial to ensure a good crop development. Rice can be negatively affected by low temperatures during reproductive stage. Then, it is very important that reproductive stage occurs at the same time optimum radiation offer, to meet the highest photosynthesis demand of the crop. In the last decade, it has been observed how weather conditions are increasingly variable. Extreme high or low temperatures are registered in the middle of summer season when rice is flowering (most susceptible stage to cold damage). In this study, the effect of sowing sate 10 years, 2 different locations and two japonica rice varieties, on four critical traits for temperate japonica rice cultivation is analyzed. Zafiro INIA and Cuarzo INIA are the most cultivated rice varieties covering 90% of Chilean rice production area.

Five different sowing dates (late September, early October, late October, early November and late November) were evaluated under a split plot design where the two rice varieties mentioned above were randomly replicated 3 times with other 6 genotypes (which are not analyzed in this study because they were no present in all years under evaluation). The evaluation was done during 10 years from season 2008 through 2018 in two locations (Parral and San Carlos). In order to evaluate the effect of sowing dates through years, location and varieties a factorial analysis of 5 levels was carried out for four critical traits (Yield, Days to heading, Whole grain percentage and Sterility).

Results indicated that the significantly highest yield was observed when the two rice varieties were established during the second half of October (or late October). Regarding to yield analyzed by varieties, there were no significantly differences between Zafiro INIA and Cuarzo INIA. Observed yield for both varieties was significantly higher in San Carlos than in Parral. During the last 10 years the highest yield was observed during season 2011/2012. Regarding to the Days to Heading (DTH), the shortest cycle (around 100 days from sowing to flowering) was observed with the latest sowing date (late November). And San Carlos (111 days in average) showed significantly longer plant growth cycle than Parral (105 DTH). During the last 10 years the shortest number of days to heading was observed during season 2008/2009. For whole grain (rice industrial quality) there were no significantly differences neither among different sowing dates nor for the locations or varieties. Significantly lower percentage of whole grain was observed during season 2009/2010. Finally for Sterility significantly higher percentage of sterile grains was observed when rice was established during November (late and early respectively). There were no significantly differences between Zafiro INIA and Cuarzo INIA. Significantly higher levels of sterility were observed in San Carlos and in season 2009/2010.

Chilean rice is the southernmost rice production in the world. For this reason only temperate japonica rice can be grown in the country. This type of rice has been adapted to shorter growing seasons, flowering in longer days allowing their cultivation in summer seasons (avoiding winters) of the cooler areas (Naranjo et al., 2014). In order to success obtaining high yields at the end of the season, a correct crop establishment must to be done. As it was stated before, Chilean rice has a narrow sowing date window. Choosing the correct sowing date will have an important impact in the four critical traits studied (yield, Whole grain, DTH and Sterility). As Patel et al., (2019) stated, correct sowing time will ensure a crop that will develop with their cold sensitive stages away from the occurrence of low temperatures. Also it will allow a good grain filling during late summer and early autumn when temperatures still are mild which will translate in good grain quality. In the present study it was observed that better yields can be reached establishing the rice plants during the second half of October (around October the 20th) considering yields obtained during the last 10 years, two main rice cultivated location and two most planted rice cultivars. Using this sowing date (late October), the number of days to heading is around 110 which still classify as a long growth cycle the Chilean rice varieties. Rice farmers have been always asking for shorter cycle varieties, but as it is observed in this study, shorter cycles (sowing date in late November) implies lower yields and higher sterilities of grain. Efforts to breed early maturity varieties are currently done by the Chilean rice Breeding Program at INIA where Zafiro INIA and Cuarzo INIA - used in this study - were breed. Analyzing the performance of the two most cultivated Chilean varieties during the last 10 years allows considering different weather scenarios. Sterility is a trait used to indirectly measure the cold tolerance in Chilean rice. During season 2009/2010 the highest level of sterility was observed and lowest yield for both varieties. This particular season was a cold summer season that produced high grain sterility in the country which decreased average national yield from 6.5 t/ha to 3.0 t/ha. It is important to analyze a long term experiment and local data that allows monitoring this extreme weather events and how it affects rice performance.

With the results obtained in this study, it can be concluded that the safest sowing date would be second half of October, considering all weather variations presented during last 10 years. This also can contribute to ensure the food security of the country.

Key words: japonica rice, sowing date, *Oryza sativa L.*, yield.

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Towards a more sustainable rice crop: the Rice System Intensification (SRI) experience in Chilean temperate japonica rice

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ABSTRACT

SRI is a set of climate-smart agroecological practices to increase rice productivity and sustainability by changing plant density, soil, water and nutrients, reducing the inputs. Even though this system has been widely used in the world; no experiences in low temperature environments have been done. To face challenging cropping conditions generated as consequences of climate change, the study of more sustainable practices are required to be able to increase the rice production. Therefore, modified SRI was studied.

Four cropping systems were established in Parral, during 2017/2018. SRI-1, SRI-2, Conventional flooding (CF) and Conventional direct sow (CDS) were conducted in RCBD with three replications. Zafiro-INIA a temperate japonica variety was used. SRI-1 consisted: 2 leaves seedlings (one plant) were transplanted in 30x30cm grid and irrigated every 8 days (weeds were controlled mechanically). SRI-2 consisted in same water and weed management as SRI-1, but 3 leaves seedlings (2 plants) were used (grid 30x12cm). CF used pregerminated seeds (160 kg/ha) and continuous flooding conditions. Weeds were controlled by herbicides. For CDS, dry seeds (140 kg/ha) were sown and irrigated twice before continuous flooding. Grain yield, sterility percentage, grain quality, days to heading, tillers number; total grain number was evaluated among others.

The best yield (8 ton/ha) was CF mainly due to the weed control and thermic buffer water effect. Followed by CDS (7 t/ha), SRI-2 (6.5 t/ha) and SRI-1 (5.4 t/ha). All treatments obtained high grain quality (over 60%). SRI-1 showed in average more than 30 productive tillers per plant, meanwhile conventional methods only 7. Even though SRI methods didn't get maximum productive levels, the results are promising considering that 6.5 t/ha were produced using only a third of water used conventionally. This shows that it is possible to produce rice in Chile not using the thermic protection of water.

Key words: japonica rice, sustainable rice, *Oryza sativa L.*, SRI.

Towards a more sustainable rice crop: the Rice System Intensification (SRI) experience in Chilean temperate japonica rice

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Introduction

SRI is a set of climate-smart agroecological practices to increase rice productivity and sustainability by changing plant density, soil, water and nutrients, reducing the inputs. Even though this system has been widely used in the world; no experiences in low temperature environments have been done. To face challenging cropping conditions generated as consequences of climate change, the study of more sustainable practices are required to be able to increase the rice production.

Objective

- Introduce, adapt and validate basic SRI's principles to Chilean rice productive conditions.
- Increase the sustainability in agronomic practices utilized in Chilean rice production.

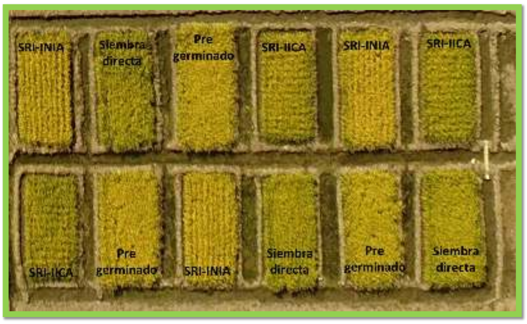

Fig 1. Aerial view of different treatments under study in Parral, Chile, season 2016-2017.

Material and Methods

Four cropping systems were established in Parral, during 2017/2018. SRI-1, SRI-2, Conventional flooding (CF) and Conventional direct sow (CDS) were conducted in RCBD with three replications. Zafiro-INIA a temperate japonica variety was used. SRI-1 consisted: 2 leaves seedlings (one plant) were transplanted in 30x30cm grid and irrigated every 8 days (weeds were controlled mechanically). SRI-2 consisted in same water and weed management as SRI-1, but 3 leaves seedlings (2 plants) were used (grid 30x12cm). CF used pregerminated seeds (160 kg/ha) and continuous flooding conditions. Weeds were controlled by herbicides. For CDS, dry seeds (140 kg/ha) were sown and irrigated twice before continuous flooding. Grain yield, sterility percentage, grain quality, days to heading, tillers number; total grain number was evaluated among others.

Fig 2 and 5. Different treatments under study in Parral, Chile, on left four treatments in vegetative stages, on right, irrigated treatments and farmers extension activities

Results

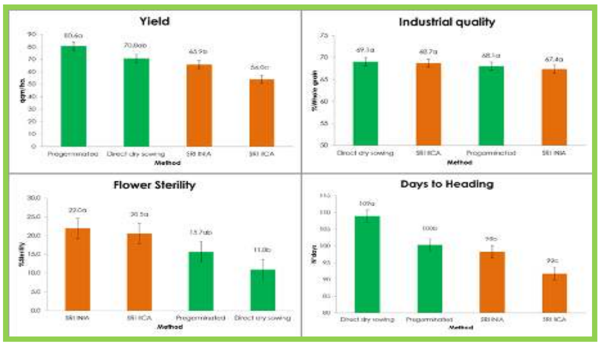

Fig 3. Agronomic traits evaluated under four treatments. Different letters means significant differences among treatments under Test:LSD Fisher Alfa=0.05

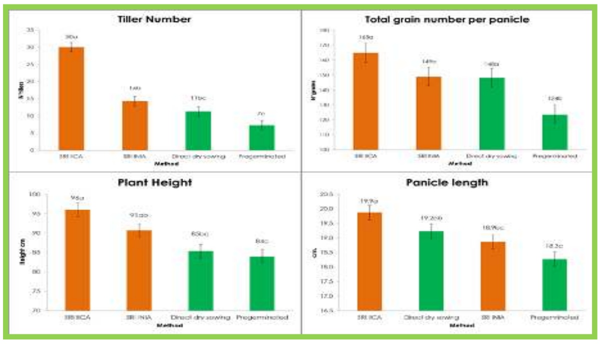

Fig 4. Yield components evaluated under four treatments. Different letters means significant differences among treatments under Test:LSD Fisher Alfa=0.05

The best yield (8 ton/ha) was CF mainly due to the weed control and thermic buffer water effect. Followed by CDS (7 t/ha), SRI-2 (6.5 t/ha) and SRI-1 (5.4 t/ha). All treatments obtained high grain quality (over 60%). SRI-1 showed in average more than 30 productive tillers per plant, meanwhile conventional methods only 7. Even though SRI methods didn't get maximum productive levels, the results are promising considering that 6.5 t/ha were produced using only a third of water used conventionally. This shows that it is possible to produce rice in Chile not using the thermic protection of water.

Conclusions

- SRI principles are suitable for rice cultivation under cold stress.
- Rice production in Chile could increase using SRI and WUE varieties

Seed dormancy in *Aeschynomene denticulata* and *Aeschynomene indica*

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ABSTRACT

The species comprehended in the *Aeschynomene* genus are considered the most troublesome broadleaved-weeds for rice production in southern Brazil. As a Fabaceae, this species' seeds may exhibit some dormancy mechanism. Therefore, this work hypothesis is that the seeds of *Aeschynomene denticulata* and *Aeschynomene indica* have exogenous dormancy, and it's objective is to determine if the dormancy occurs in both species and which is the most efficient method to break it. Seeds used on the experiment were collected at Embrapa Clima Temperado Research Station, one month prior to the experiments start, from different adult plants. On the first experiment, germination tests were conducted on gerboxes with 50 seeds and 15mL of destilled water, under a completely randomized design with four repetitions in a germination chamber (25°C/12h light). For the second experiment germination tests were conducted using the same methods described for the first experiment, but introducing the dormancy breaking methods, which were: preheating (35°C/72h), precooling (10°C/72h), potassium nitrate (0.2%) soaking, giberelic acid (0.5%), water soaking, mechanical scarification and chemical scarification (sulfuric acid 1%/1min). Both experiments were repeated two times and germination was evaluated five and eight after sowing. After the second germination counting seed viability was evaluated through the tetrazolium test. Data collected was analyzed using the Tukey test. Results from the first experiment confirmed the proposed hypothesis and showed no statistical difference between the species, indicating that some degree of dormancy is present, as germination means were always below 3%. For the second experiment the best method for dormancy breaking for both species was the mechanical scarification, which significantly increased seed germination around 8 times for *A. denticulata* and 30 times for *A. indica*. Hence, a hypothesis can be layed down for future work: does soil contact with the seed during tillage sufficient to mechanically break *Aeschynomene* seed dormancy?

Key words: jointvetch, dormancy, rice, weed.

Seed dormancy in *Aeschynoemene denticulata* and *Aeschynomene indica*

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Introduction

- The species comprehended in the *Aeschynomene* genus are considered the most troublesome broadleaved-weeds for rice production in southern Brazil.

- As a Fabaceae, this species' seeds may exhibit some dormancy mechanism.

Objective

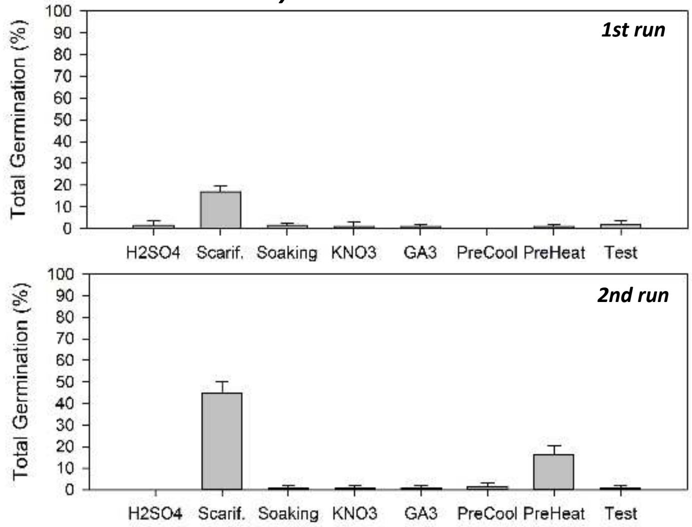
- To determine if the dormancy occurs in both species and which is the most efficient method to break it.

Material and Methods

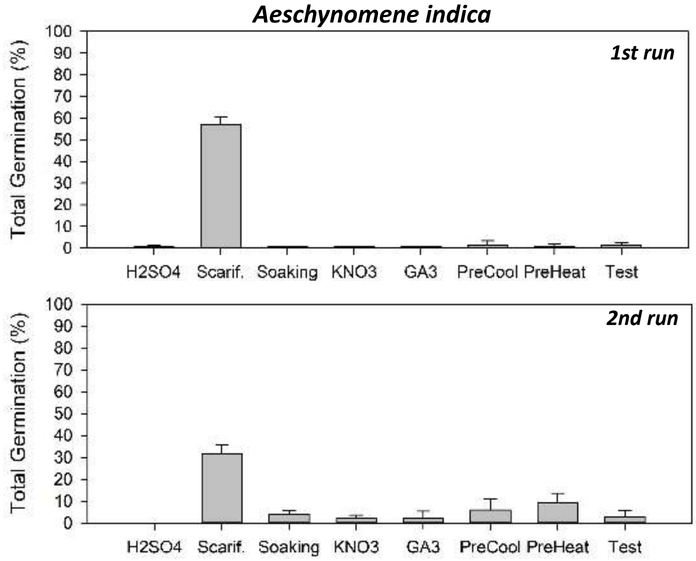
- Seeds used on the experiment were collected at Embrapa Clima Temperado Research Station, one month prior to the experiments start, from different adult plants.
- On the first experiment, germination tests were conducted on gerboxes with 50 seeds and 15mL of destilled water, under a completely randomized design with four repetitions in a germination chamber (25°C/12h light).
- For the second experiment germination tests were conducted using the same methods described for the first experiment, but introducing the dormancy breaking methods, which were:
  - Preheating (35°C/72h),
  - Precooling (10°C/72h),
  - Potassium nitrate (0,2%)
  - Soaking in giberelic acid (0,5%),
  - Water soaking,
  - Mechanical scarification and
  - Chemical scarification (sulfuric acid 1%/1min).
- Both experiments were repeated two times and germination was evaluated five and eight days after sowing.
- After the second germination counting seed viability was evaluated through the tetrazolium test.
- Data collected was analyzed using the Tukey test.

Results

Aeschynomene denticulata



Aeschynomene indica



- A new hypothesis can be layed down for future work: does soil contact with the seed during tillage enough to mechanically break *Aeschynomene* seed dormancy?

Conclusions

- Seeds of *A. denticulata* e *A. indica* presented exogenous dormancy, which can be break using mechanical scarification on the seed coat.

Seasonal Greenhouse Gas Emissions of Irrigated Rice Cultivars

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ABSTRACT

Rice is one of the most cultivated cereals worldwide, however irrigated rice is a large source of greenhouse gases (GHG) in agriculture, particularly methane (CH_4). Selection of rice cultivars with low CH_4 emission has been a promising strategy to mitigate the impact of rice paddies. This study had the objective of evaluating the potential of CH_4 and nitrous oxide (N_2O) emissions of some Brazilian irrigated rice cultivars. The study was conducted in Southern Brazil from November 2017 to May 2018, using two hybrids (XP113 and XP118 CL) and two conventional rice cultivars (BRS Pampa CL and BRS Pampeira). The air sampling for CH_4 and N_2O soil emissions analysis was performed at least once a week, using static closed chambers. Seasonal N_2O emissions differed among rice cultivars. XP118 CL and XP113 hybrids had, respectively, the highest (8.48 kg N_2O ha^{-1}) and the lowest total N_2O emissions (0.71 kg N_2O ha^{-1}), while conventional rice cultivars had intermediate N_2O emissions. Seasonal CH_4 emissions of the rice cultivars decreased in the following order: XP118 CL (319.2 kg CH_4 ha^{-1}) > BRS Pampa CL (248.3 kg CH_4 ha^{-1}) > BRS Pampeira (184.8 kg CH_4 ha^{-1}) > XP113 (102.1 kg CH_4 ha^{-1}). XP118 CL hybrid had the highest global warming potential (GWP) (10,507 kg CO_2eq. ha^{-1}) among the evaluated cultivars, which was 2.7; 1.9; and 1.5 times greater than XP113; BRS Pampeira; and BRS Pampa CL (3.8; 5.4; and 7.0 kg CO_2eq. ha^{-1}, respectively). Yield-scaled GWP of the rice cultivars was approximately similar to their GWP, presenting the following values: XP118 CL= 0.88; BRS Pampa CL= 0.74; BRS Pampeira= 0.50; and XP113= 0.37 kg CO_2eq. kg^{-1}). These findings highlight the importance of choosing suitable rice cultivars to mitigate GHG emissions. Therefore, the relation between greenhouse gas emissions and yield grains also must be considered.

Keywords: paddy rice, methane, nitrous oxide, global warming potential.

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Seasonal Greenhouse Gas Emissions of Irrigated Rice Cultivars

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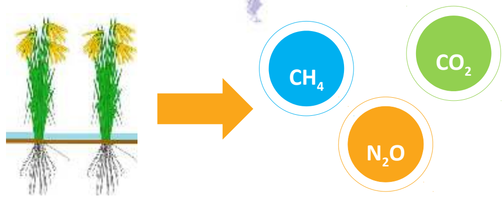
Introduction

- Rice is one of the most cultivated cereals worldwide



- Irrigated rice is a large source of greenhouse gases, particularly methane (CH_4)

✓Selection of rice cultivars with low CH_4 emission has been a promising strategy to mitigate the impact of rice paddies.

Objective

To evaluate the potential of methane (CH_4) and nitrous oxide (N_2O) emissions of four Brazilian irrigated rice cultivars.

Material and Methods

- Local: Terras Baixas Experimental Station of Embrapa Temperate Agriculture, Capão do Leão, State of Rio Grande do Sul, Brazil
- Soil: Planossolo Háplico (Typic Albaqualf)
- Rice season 2017/2018: November 2017 to May 2018
- Treatments - rice cultivars: two conventional cultivars (BRS Pampa CL and BRS Pampeira) and two hybrids (XP113 and XP118 CL)
- Completely randomized design, with three replications
- CH_4 and N_2O evaluations: static chamber method
- Sampling frequency: once a week (9:00 h to 11:00 h AM)
- Measured variables: CH_4 and N_2O fluxes, seasonal N_2O and CH_4 emissions, Global Warming Potential (GWP), and Yield-scaled GWP
- Statistical analysis: ANOVA – Tukey test ($p < 0.05$)

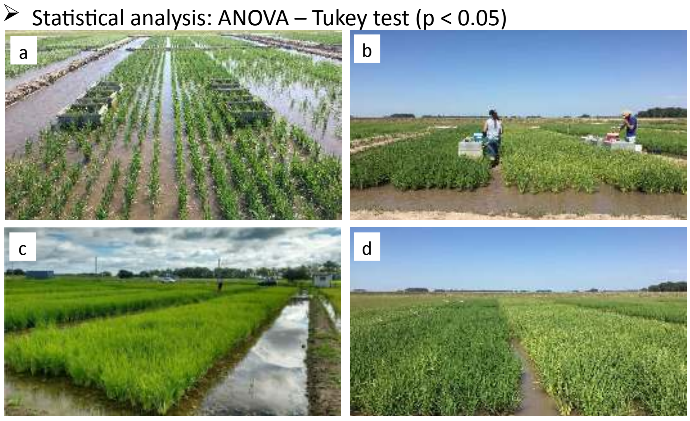


Figure 1. Experimental area cultivated with irrigated rice cultivar in different phases of the growing season (a, b, c, and d).

Results

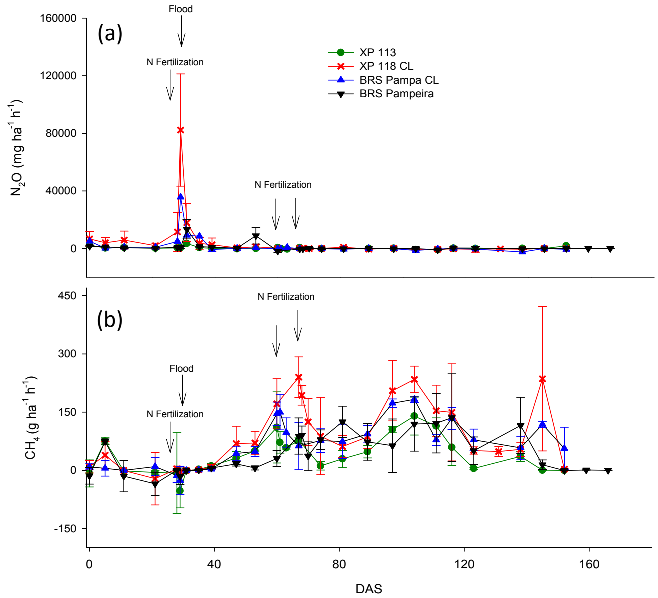


Figure 3. CH_4 (a) and N_2O (b) fluxes from rice cultivars during growing season 2017/2018. Error bars represent the standard error of the Means. Capão do Leão-RS, Brasil.

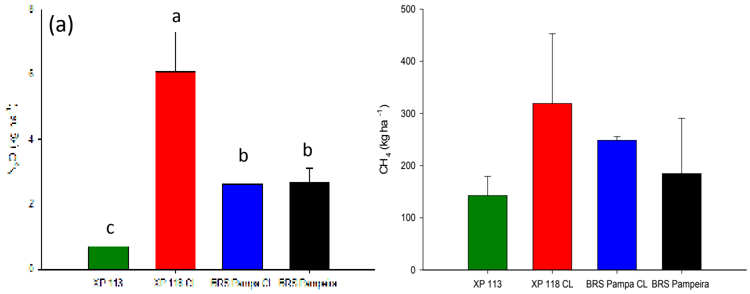


Figure 3. Seasonal N_2O (a) and CH_4 (b) emissions from rice cultivars during growing season 2017/2018. Means not sharing a letter are significantly different according to Tukey test (0.05).

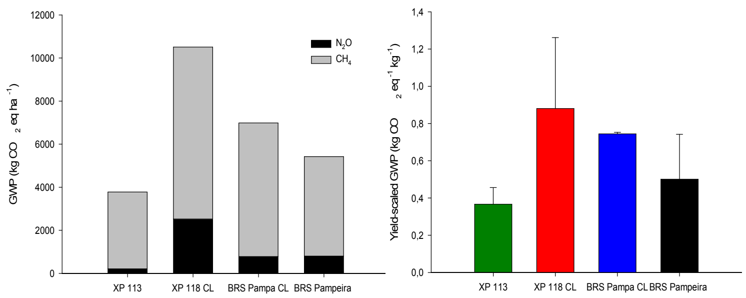


Figure 4. Global Warming Potential (GWP) (a) and yield-scaled GWP (b) from rice cultivars during growing season 2017/2018. Means not sharing a letter are significantly different according to Tukey test (0.05).

Conclusions

XP 118 CL hybrid presents CH_4 and N_2O emissions, GWP, and yield-scaled GWP higher than XP 113, BRS Pampeira and BRS Pampa CL cultivars.

BRS Pampeira and XP 113 are promising cultivars to mitigate greenhouse gas emissions in southern Brazil rice paddies.

Effects of Nitrogen Sources on Greenhouse Gas Emission in Temperate Irrigated Rice

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ABSTRACT

Enhanced-efficiency nitrogen fertilizers are sources of nitrogen (N) capable of inhibiting or delaying soil enzymatic and microbial processes. A field trial was conducted to assess nitrous oxide (N_2O) and methane (CH_4) emissions, global warming potential (GWP) and yield-scaled global warming potential (GWP_y) in temperate rice paddy fertilized with soluble and enhanced-efficiency nitrogen sources. The experiment was conducted in a Typic Albaqualf in Southern Brazil. The treatments were (i) no N (control), (ii) urea, (iii) urea + urease inhibitor N-(n-butyl) thiophosphoric triamide (urea+NBPT), (iv) urea + nitrification inhibitor dicyandiamide (DCD), (v) urea+NBPT+DCD, (vii) sulfur coated urea (urea+S), and (vii) copper and boron coated urea (Urea+Cu+B). Nitrogen sources were applied at the rate of 120 kg ha^{-1} of N. Measurements of CH_4 and N_2O fluxes were performed using static chambers with three replications. The measurements were conducted at least once a week throughout rice-growing season. The enhanced-efficiency fertilizers showed N_2O emission similar to urea. The average cumulative N_2O emission from N fertilizers was significantly higher than no N treatment. The largest N_2O emissions were observed before soil flooding and right after the onset of flooding, indicating that the availability of mineral forms of N in the soil and alternating nitrification and denitrification processes intensify N_2O losses. There was no difference in CH_4 emissions among treatments; average cumulative CH_4 emission corresponded to 404 kg ha^{-1}. In general GWP of enhanced-efficiency nitrogen fertilizers was similar, except for Urea+S treatment (13,988 kg CO_2eq. ha^{-1}), which provided higher GWP than Urea+NBPT (9,931 kg CO_2eq. ha^{-1}). The measured GWP were high, however values above 7,000 kg CO_2eq. ha^{-1} are frequent in irrigated rice. Enhanced-efficiency nitrogen sources did not influence GWP_y, with an average of 1.43 kg CO_2eq. kg^{-1}. Enhanced-efficiency nitrogen fertilizers provide N_2O and CH_4 emissions, GWP and GWP_y similar to urea in temperate irrigated rice.

Keywords: paddy rice, enhanced-efficiency nitrogen fertilizer, methane, nitrous oxide.

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Effects of Nitrogen Sources on Greenhouse Gas Emission in Temperate Irrigated Rice

Thaís A. Veçozzi[1]; Walkyria B. Scivittaro[2]; Rogério O. Sousa[1], Thaís M. Jardim[1]; Anderson D. Silveira[1]; Nathália F. Lucas[1]

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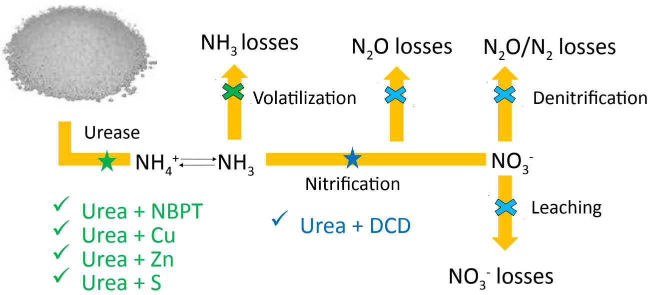
Introduction



Enhanced-efficiency nitrogen fertilizers are sources of nitrogen (N) capable of inhibiting or delaying soil enzymatic and microbial processes.

Objective

To assess nitrous oxide (N_2O) and methane (CH_4) emissions, global warming potential (GWP) and yield-scaled global warming potential (GWP_y) in temperate rice paddy fertilized with soluble and enhanced-efficiency nitrogen sources.

Material and Methods

- Local: Terras Baixas Experimental Station of Embrapa Temperate Agriculture, Capão do Leão, State of Rio Grande do Sul, Brazil
- Soil: Planossolo Háplico (Typic Albaqualf)
- Rice season 2016/2017
- Rice cultivar: Puitá Inta CL
- Experimental design of randomized blocks, with 3 replications
- Treatments:

Control: no N

Urea: urea at four-leaf stage (V4) and panicle initiation stage (R0)

BPT: urea + urease inhibitor N-(n-butyl) thiophosphoric triamide

Ureia+DCD: urea + nitrification inhibitor dicyandiamide

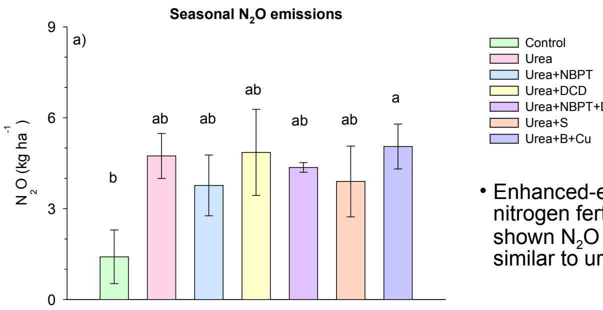
Ureia+NBPT+DCD

Ureia+S: sulfur coated urea

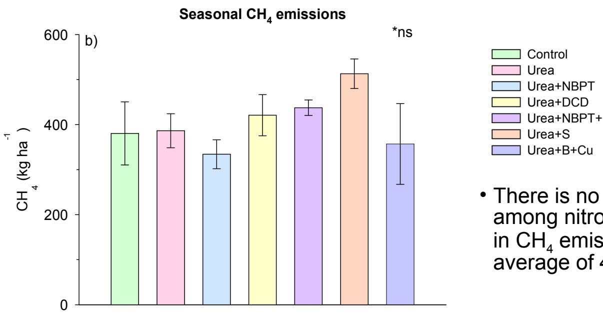
Ureia+Cu+B: copper and boron coated urea

- Split application of nitrogen fertilizers: 60% at four-leaf stage (V4) + 40% at panicle initiation stage (R0)
- CH_4 and N_2O evaluations: static chamber method
- Sampling frequency: at least once a week (9:00 h to 11:00h AM)
- Measured variables: CH_4 and N_2O fluxes, seasonal N_2O and CH_4 emissions, Global Warming Potential (GWP), and Yield-scaled GWP
- Statistical analysis: ANOVA – Tukey test ($p < 0.05$)

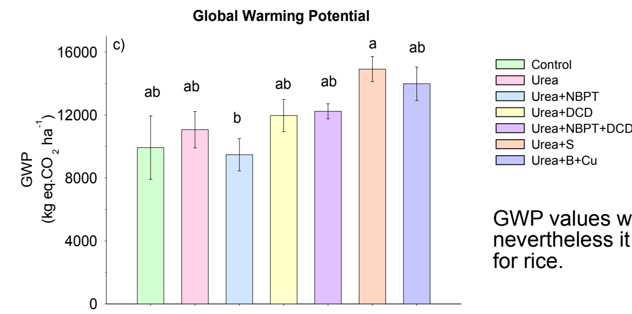
Results



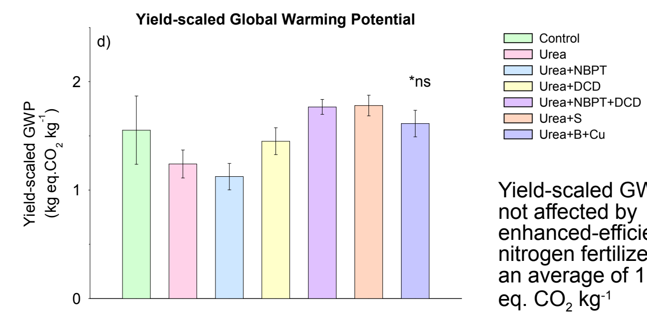
- Enhanced-efficiency nitrogen fertilizers have shown N_2O emissions similar to urea.



- There is no difference among nitrogen sources in CH_4 emissions with an average of 404 kg ha^{-1}.



GWP values were high, nevertheless it is usual for rice.



Yield-scaled GWP was not affected by enhanced-efficiency nitrogen fertilizers with an average of 1,43 kg eq. CO_2 kg^{-1}

Conclusions

Enhanced-efficiency nitrogen fertilizers provide similar N_2O and CH_4 emissions, GWP and yield-scaled GWP to urea in irrigated rice.

CONTINUOUS FLOOD WITH INTERMITTENT SUPPLY OF IRRIGATION WATER IN RICE

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ABSTRACT

Embrapa Temperate Agriculture is recommending the continuous flood with an intermittent supply of irrigation water as an alternative management strategy for the irrigated rice crop. This is particularly relevant in rice-producing regions of the Rio Grande do Sul State where there is a scarcity of irrigation water. By employing the system there is an expressive reduction in the use of stored water and better utilization of the rainwater which occurs along the crop cycle. This management consists of establishing a water depth of 10 cm in the vegetative growth stage V3-V4. Afterward, the water is allowed to drop naturally to replace water up to the height of the spillway (10 cm). The area is irrigated during the rice cycle whenever the height of the water layer approaches zero (saturated soil). This procedure must be carried out until the moment in which the water supply by pumping is suppressed (beginning of the grain filling stage). Knowing the crop development stages in respect to the plant's tolerance to lack of water is an important factor to be considered in irrigation using this system. Equally important is to know when the water supply is necessary, as at the times of Nitrogen application, for example. Among the advantages of this system are reduced cost of electricity for irrigation; better use of rainwater, which can reach up to 80%; better water distribution on the farm; increased planting area, and productivity similar to the continuous irrigation system, without impairing the weed control and nutrient availability.

Key words: water management, rice irrigation, Oryza sativa.

Sowing date and soil moisture influence *Aeschynomene* seedling emergence

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ABSTRACT

The species comprehended in the *Aeschynomene* genus are considered the most troublesome broadleaved-weeds for rice production in Southern Brazil. Sowing date and flood irrigation are the main cultural practices that favor rice against weeds. Therefore, this work hypothesis is that early sowing and continuous flood irrigation can reduce *Aeschynomene* spp. seedling emergence, and it's objective is to determine which environmental conditions are the most propitious for this species emergence and establishment. Seeds used on the experiment were collected at Embrapa Clima Temperado Research Station, two months prior to the experiment start, from different *A. denticulata* and *A. indica* adult plants and were cleaned and mechanically scarified with sandpaper for experiment installation. The experiment was set in a completely randomized design with five replications and two factors. Factor A was composed of four soil moisture conditions: field capacity, saturation, continued flood and intermittent flood (water removal seven days after sowing), and Factor B was composed of three growth chamber-simulated sowing dates: September (11-19°C/11h36min of light), October (13-22°C/11h52min of light) and November (15-25°C/12h50min of light). The temperature and light time for each month was based on the averages of a 30-year data-set (1971-2000) from the Pelotas Weather Station. Seedling emergence was counted until 21 days after sowing and then data collected was analyzed and fit to a four parameters log-logistic model. Seedling emergence for both species and three simulated sowing dates was null when flood was present during the 21 days after sowing. For the other treatments an increase in emergence of both species was observed and data successfully adjusted to the model ($R^2 \geq 0.97$). As expected, seedling emergence was faster and greater in the higher temperatures from October and November for both species than the low temperatures from September. After water removal from the intermittent flood treatment, seedling emergence was observed.

Key words: jointvetch, temperature, flood, rice.

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Embrapa Clima Temperado

Universidade Federal de Pelotas RS - Brasil

Sowing date and soil moisture influence *Aeschynomene* seedling emergence

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Introduction

- The species comprehended in the *Aeschynomene* genus are considered the most troublesome broadleaved-weeds for rice production in southern Brazil.

- Sowing date and flood irrigation are the main cultural practices that favor rice against weeds.

Objective

- To determine which environmental conditions are the most propitious for this species emergence and establishment.

Material and Methods

- Seeds used on the experiment were collected at Embrapa Clima Temperado Research Station, two months prior to the experiment start, from different *A. denticulata* and *A. indica* adult plants and were cleaned and mechanically scarified with sandpaper for experiment installation.
- The experiment was set in a completely randomized design with five replications and two factors:
  - **Factor A - four soil moisture conditions:**
  - field capacity,
  - saturation,
  - continued flood and,
  - intermittent flood (water removal 7 DAS).
  - **Factor B - three growth chamber-simulated sowing dates:**
  - September (11-19°C/11h36min of light),
  - October (13-22°C/11h52min of light) and,
  - November (15-25°C/12h50min of light).
- The temperature and light time for each month was based on the averages of a 30-year data-set (1971-2000) from the Pelotas Weather Station.
- Seedling emergence was counted until 21 days after sowing
- Data collected was analyzed and fit to a four parameters log-logistic model.

Results

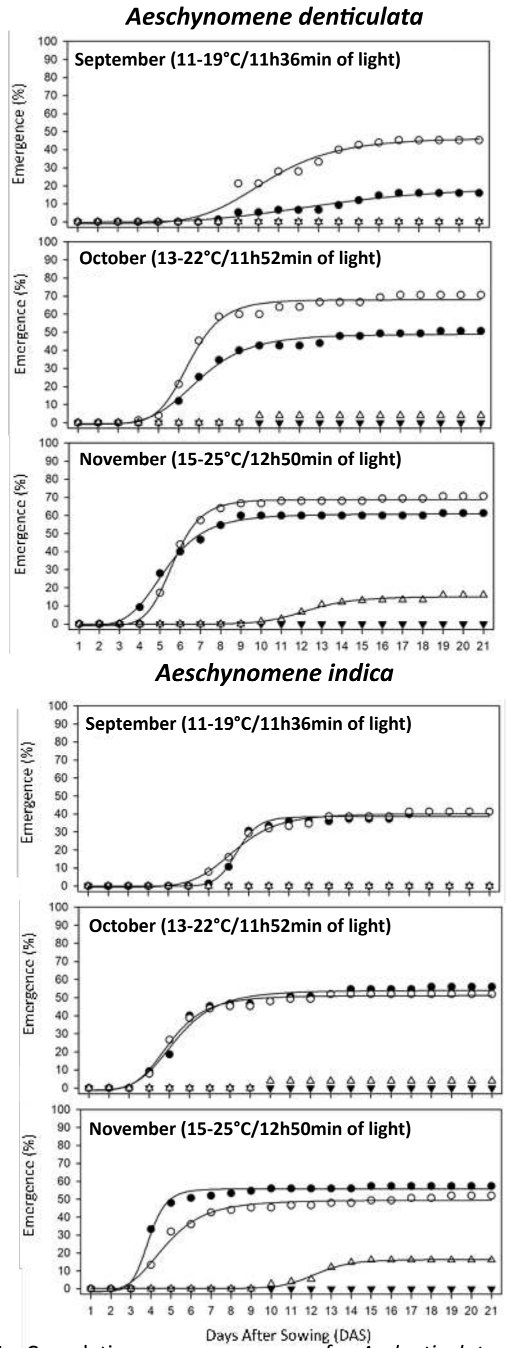

Figure 1 - Cumulative emergency curves for *A. denticulata* and *A. indica* in different soil moisture conditions: ● - Field capacity; ○ - Saturation; ▼ - Continuos flood and Δ - intermittent flood .

Conclusions

- As expected, seedling emergence was faster and greater in the higher temperatures from October and November for both species than the low temperatures from September. After water removal from the intermittent flood treatment, seedling emergence was observed.

Embrapa ITRC INIA Uruguay SOSBAI

7 *Rice economics and marketing*

Is Brazilian rice immune to shocks?

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ABSTRACT
This paper aimed to analyze the behavior of the Brazilian rice market in the face of exogenous shocks. Therefore, time series of exports, imports and prices received by farmers in Brazil from January 1997 to October 2019 were used to estimate the fractional differentiation parameter Gaussian Semiparametric Estimator (GSE), based on the frequency domain Whittle Function. Brazilian rice market is persistent to external shocks, with the presence of long memory in exports, imports and prices received by farmers.

Key words: Rice market, rice exports, rice imports, rice prices, long memory.

1. Introduction

Brazil is among the largest producers and consumers of rice worldwide. In addition, it has a large consumer market and rice is an essential and widely consumed staple food among Brazilian families. Average per capita consumption of the Brazilians is approximately 36 kg per year. Per capita consumption varies regionally and has declined over time in Brazil (Wander and Chaves, 2011).

Given this, the objective of this paper is to analyze the behavior of the Brazilian rice market in the face of exogenous shocks. In other words: is this market susceptible to shocks coming from the international or national market? Is it a mature or still consolidating market? Specifically, it seeks to test the presence of long memory in the series, to verify the existence of structural break in the data and to identify if there is heterogeneity in the behavior of the import, export and producer price series.

The contribution of this paper is based on two pillars: i) the applied methodology (fractional integration analysis: long memory test or shock persistence) has become an alternative method for understanding time series and has not been used in time series of export, import and producer prices of rice; and ii) the contribution to the understanding of the Brazilian rice market dynamics.

2. Material and Methods

2.1 Method

To achieve the objectives proposed by the present paper, each of the rice export, import and price series is denoted by y_t and its behavior will be described using the following model:

$$y_t=\beta^T Z_t+x_t, \qquad t=1,2,\ldots \tag{1}$$

where β is a vector of unknown coefficients $(k\,x\,1)$, Z_t is a set of deterministic terms that may include an intercept ($Z_t=1$), an intercept with a linear time trend ($Z_t=(1,t)^T$), or any other kind of deterministic processes and x_t are the regression errors.

According to Barros et al. (2012), the time series x_t ($t=1,2,\ldots$) is fractionally integrated in order *d* and follows a model $I(d)$ represented by:

$$(1-L)^d x_t=u_t, \qquad t=1,2,\ldots \tag{2}$$

where $(1-L)^d$ is the fractional difference operator, L is the lag operator (i.e., $Lx_t=x_{t-1}$), d is the process integration order and can be any real number and u_t is a stationary process $I(0)$, with zero mean and spectrum $f_u(\lambda)$.

The polynomial $(1-L)^d$ on the left side of Equation (2) can be expressed in terms of binomial expansion for any real number d:

$$(1-L)^d=\sum_{j=0}^{\infty}\psi_j L^j=\sum_{j=0}^{\infty}\binom{d}{j}(-1)^j L^j=1-dL+\frac{d(d-1)}{2}L^2-\ldots\text{, i.e.,}$$
$$(1-L)^d x_t=x_t-d\,x_{t-1}+\frac{d(d-1)}{2}x_{t-2}-\ldots$$

Barros et al. (2011, 2016) point out that parameter d, represented by equation (2), plays a crucial role in data analysis, because it is an indicator of the degree of dependence of the series. The higher the value of d, the greater the level of association between observations that are increasingly distant in time.

In the case of $d=0$ in (2), the stochastic process x_t has a stationary covariance. If the fractional parameter assumes a value of $d=1$, x_t is a non-stationary process with a unit root, that is, the model contains a stochastic tendency. Thus, fractional integration arises when d assumes positive rather than integer values, $0<d<1$. If the value of d is restricted to the range $0<d<0{,}5$, x_t is mean reversal and remains a steady-state covariance process, but with the decay of the autocovariance function slower than in the steady-state case, $I(0)$. If $0{,}5\leq d<1$, x_t is non-stationary but reversed to mean and its self-covariance function exhibits greater persistence (Apergis and Tsoumas, 2011, 2012). However, if $d\geq1$, x_t is non-stationary and not mean-reversed (Gil-Alana, 2008).

Processes with $d>0$ in equation (2) exhibit the "long memory" property, so-called because of the strong degree of association between observations that are very distant in time (Barros et al., 2016). Impulse responses are also affected by the magnitude of d, according to Barros et al. (2011), the higher the value of d, the higher the answers. In the case of $d<1$, the series is reversed to average, with shocks of temporary effects and disappearing over the long term. However, if $d\geq1$, the shock will have permanent effects unless strong policy measures are taken.

In the context of fractional processes, Gil-Alana (2008) points out that occasionally neglecting structural breakdowns can lead to the discovery of spurious long memory. Therefore, this paper examines the possibility of fractional integration in the presence of a single structural break at an unknown point within the sample. Thus, each of the series, y_t, which presents break is represented according to the following model:

$$y_t=\beta_1^T+x_t;\qquad (1-L)^{d_1}x_t=u_t,\qquad t=1,2,\ldots,T_b \tag{3}$$
$$y_t=\beta_2^T+x_t;\qquad (1-L)^{d_2}x_t=u_t,\qquad t=T_b+1,\ldots,T \tag{4}$$

where β's are the coefficients corresponding to the deterministic terms, d_1 and d_2 are real numbers, u_t is a stationary process $I(0)$, with zero mean and spectrum $f_u(\lambda)$ and T_b is the unknown break point.

The methodology used in the present study to estimate the fractional differentiation parameter is the method proposed by Robinson et al. (1995), the Gaussian Semiparametric Estimator (GSE) based on the frequency domain Whittle Function. Also the test proposed by Andrews and Ploberger (1994) is applied, with p-value using the Hansen (1997) approximations, which is recommended for testing a single structural break at an unknown point within the sample and identifying the break date, T_b. Also. Subsequently, new estimates of parameter d are made in the presence of breakage[1].

2.2 Data

Monthly export and import amount data from January 1997 to October 2019 (N=274) were obtained from Comex Stat (MDIC, 2019). Time series is presented in Figure 1.

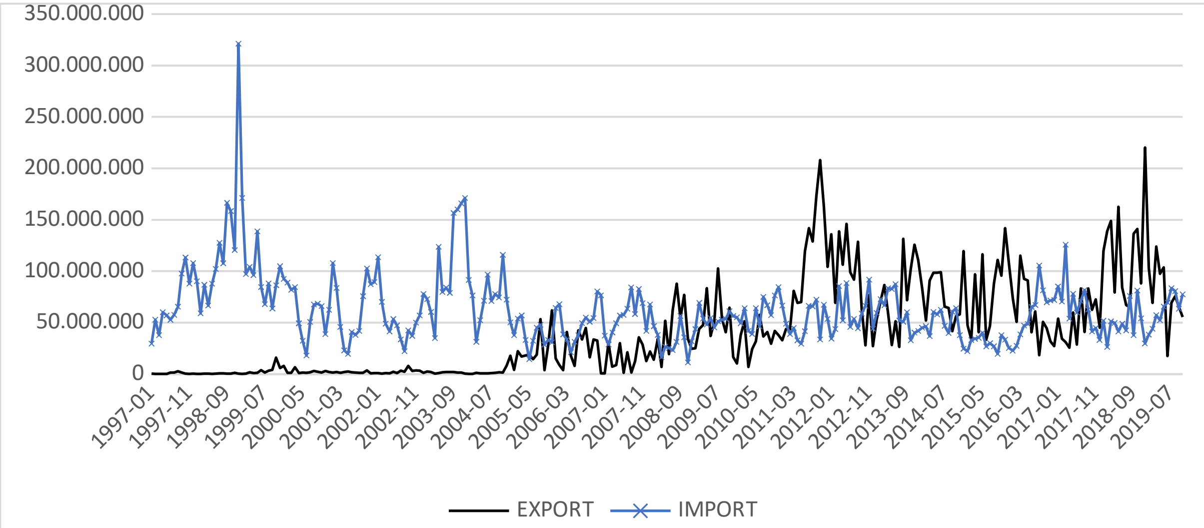
Monthly rice prices received by farmers from January 1997 to October 2019 (N=274) were obtained from Instituto de Economia Agricola (IEA, 2019). Time series is presented in Figure 2.

Yearly data on production amount, harvested area and yield from 1996/1997 to 2018/2019 (N=23) were obtained from IBGE (2019a, 2019b).

1 The econometric software used to perform the statistical procedures of this study is the Regression Analysis of Time Series (RATS 9.2) and its complement, the Cointegration Analysis of Time Series (CATS).

While imports occur over the whole period, export become relevant after 2004, when the Brazilian production reached self-sufficiency level. Rice prices received by farmers show a cyclic decrease tendency over time. Some export peaks occurred in low-prices periods.

Figure 1. Brazilian rice export and import amounts (metric tons), January 1997 – October 2019.



Source: MDIC (2019). Own preparation.

Figure 2. Rice price receive by farmers in Brazil (R$/60kg), January 1997 – October 2019.

Source: IEA (2019). Own preparation.

3. Results and Discussion

Table 1 presents the results of the fractional parameter estimation. The second column contains the *d* parameter estimates by Robinson et al. (1995) for the series of exports, imports and prices paid to the producer. Disregarding the possibility of any structural breakdown, the estimates of parameter *d* of the model given by equations (1) and (2) show that for the import and export series show estimates in the range (0,1), they are fractionally integrated. While for the producer price series has estimate of the parameter greater than 1.

The rice export and import series have a high degree of persistence, $0.5 \leq d < 1$, with less significant oscillations when compared to the lower persistence series, $0 < d < 0.5$. That is, the series have a non-stationary behavior, but with reversal to the mean. Producer prices are higher than 1, indicating that a shock in the series itself will have permanent effects unless strong policy measures are adopted. That is, which shows a non-stationary behavior and no reversal to the mean.

Application of the Andrews and Ploberger (1994) test revealed a structural break in November 2004 for the export and import series and in March 2005 for producer prices. This happened because 2004/2005 was the year where Brazil had the highest domestic rice production. Given this scenario, the *d* parameters were extinguished for the series and there was only one change of behavior: for the export series after the break, which now presents an estimate of the lowest persistence parameter: $0<d<0.5$. This shows that after the break, the export market began to show more significant fluctuations, and it may occur that in one period there is a rise in volume followed by a decrease in the immediately following period.

Table 1. Estimation of the fractional parameter of the series.

	Total sample		Structural Break	Before Break			After Break		
	d	std error		d_1	std error	t_1	d_2	std error	t_2
Export	0.5342	0.0533	10/2004	0.5840	0.0822	93	0.4532	0.0630	174
Import	0.5999	0.0533	10/2004	0.7345	0.0822	93	0.6415	0.0630	174
Price	1.0401	0.0533	03/2005	1.0790	0.0801	98	1.0981	0.0598	175

Source: Research results.

d = fractional parameter of total sample; d_1 = fractional parameter before break; t_1 = observations before break; d_2 = fractional parameter after break; t_2 = observations after break.

Results are coherent with empirical rice market observation in Brazil. Analysis of the degree of persistence to shocks allows us to identify the presence of long memory in all series when considering the complete period. The presence of long memory in the series can be interpreted as a continuity of past values. For the Brazilian rice market that has a large domestic consumption and a practically self-sufficient production, this result is excellent. In other words, it shows that the market does not suffer from world market oscillations (unless they are very strong, such as severe supply shocks) and that it has a good product based on quality and surrounded by strong institutional environment.

Conclusions

Brazilian rice market is persistent to external shocks, with the presence of long memory in exports, imports and prices received by farmers.

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Economic result of rice crop in the 2019 grow season

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ABSTRACT
Knowing the costs of rice production is increasingly essential for the best development of this crop and production**.** However, few rice producers account for or analyze their costs. This research aimed to study the expenditures of the 2018/2019 growing season of 76 rice farmers in the state of Rio Grande do Sul (RS), selected randomly from the Instituto Riograndense do Arroz (IRGA) census; verifying the effect of these different variable costs on the total contribution margin, on contribution margin per bag, as well as on yield.

Key words: costs, contribution margin, correlation.

1. Introduction

The high costs of rice production in the state of Rio Grande do Sul (RS) are probably the most limiting cause for the success of rice farming. These costs of rice farming in RS are estimated annually by the State's Rice Institute (Instituto Riograndense do Arroz, IRGA), allowing to evaluate the financial result of each season of development from the economic point of view. However, these costs are general and an average for the State of RS, differentiating a few systems and types of production costs. Our research aimed to evaluate them directly with the rice farmers, in a random sampling, and to calculate the monetary result of each field studied through the contribution margin index. Moreover, the objective was to obtain and analyse significant regressions between costs and production outcomes, aiming to analyse the relationships we found.

2. Material and Methods

To collect data for this research, the IRGA census (IRGA, 2006) was initially used to obtain the farmers' contacts, selecting some at random to form a sample. Therefore, the relevant data of each selected rice farmer has surveyed by phone calls. The information obtained were name of the property, acreage, land tenure, production, value of production and machinery, quantity of urea and other fertilizers, spent fuel, seeds, interest on loans, labour expenses, aviation expenses, fungicide, insecticide and herbicides, electricity, own or outsourced drying, freight, commission expenses, contracted machinery, insurance costs, storage, technical assistance, variables expenses and environmental taxes.

The results generated were contribution margin, contribution margin per bag and yield. The contribution margin is computed as the selling price per determined crop, minus the variable cost per this crop. Also known as dollar contribution per unit, the measure indicates how a specific crop contributes to the overall profit of the farm. It provides one way to show the profit potential of a particular crop product offered by a farm and shows the portion of sales that helps to cover the farm's fixed costs. Any remaining revenue left after covering fixed costs is the profit generated.

We used the mobile software LUCRAARROZ (not yet available to the general public) developed by Embrapa Pecuária Sul. In total, 76 producers participated. The LUCRAARROZ app allows us to generate the Contribution Margin in total and per bag of rice with the data collected as well as productivity.

Then, we use the Excel application for data analysis to evaluate correlation analysis of the variables and also the regression between those that showed significant correlations.

3. Results and Discussion

The average yield of rice for the state of Rio Grande do Sul in this season was 7.508 kg/ha, according to data from the Rio-grandense Rice Institute (Instituto Rio-grandense do Arroz - IRGA, 2019). In the present study, the yield was 7,315 kg/ha on average, which is very close to that estimated by IRGA. Probably this difference is due to the low participation, in our research, of rice farmers of the southern zone of the State, where the productivity was higher (8,198 kg/ha) in the growing season 2018/ 2019.

Table 1- Correlations index (R) between costs of production, yield and contribution margin

	Area	Yield (kg/ha)	Fertilizer (kg/ha)	Urea (kg/ha)	Seed (kg/ha)	Variables expenses R$/ha	Margin/ bag
Area	1						
Yield (kg/ha)	0,083	1,000					
Fertilizer (kg/ha)	-0,339**	0,195*	1,000				
Urea (Kg/ha)	0,010	0,327**	0,396**	1,000			
Seed (kg/ha)	0,078	-0,078	-0,188	-0,083	1,000		
Variables expenses R$/ha	-0,276*	0,272*	0,154	0,134	0,093	1,000	
Margin/bag	0,227*	0,356**	0,021	0,087	-0,095	-0,757**	1

*significant at 5% of probability
** significant at 1% of probability

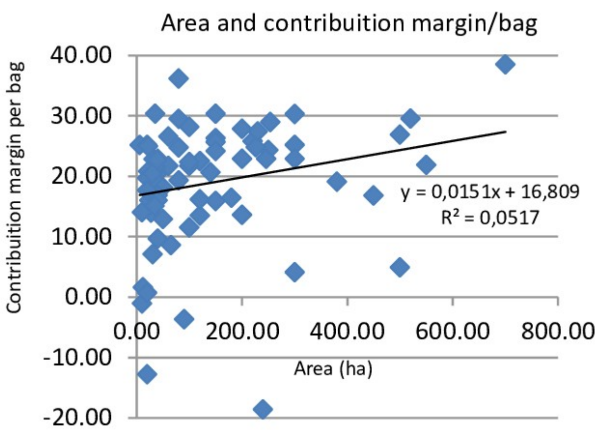

Fig.1. Regression between area (ha) and contribution margin (R$/50 kg seed bag/ha)

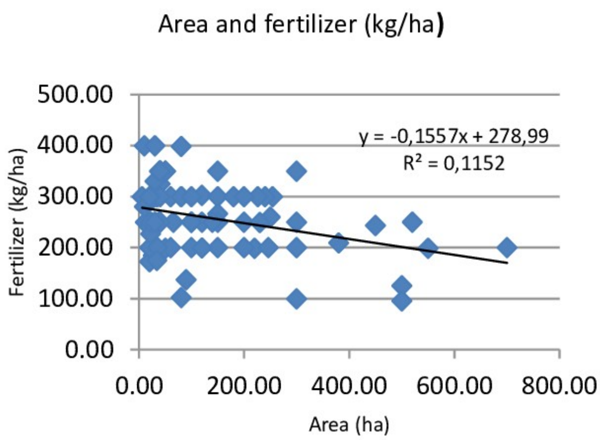

Fig.2. Regression between area (ha) and fertilizer (kg/ ha)

The area correlated significantly, at a 5% level (Table 1), with the contribution margin per bag (R = 0.227), indicating that as the area increases, the contribution margin increases. That means larger areas show better economic results, according to the positive linear regression of Fig. 1. It is normal to achieve better results when working with larger areas as a matter of scale. The census (IRGA, 2006) showed that areas larger than 250 ha produced more than smaller areas. Therefore, the smaller size of the cultivated area sets a limit for economic outcomes.

Furthermore, the area had a significant correlation with the base fertilizer (at a 1% level), presenting coefficient of correlation -0.34 (Table 1). This negative correlation indicates that larger areas use a lower amount of fertilizer per hectare (Fig.1), indicating that farmers with smaller areas use more fertilizer per hectare, thus performing a more intensive production with more costs.

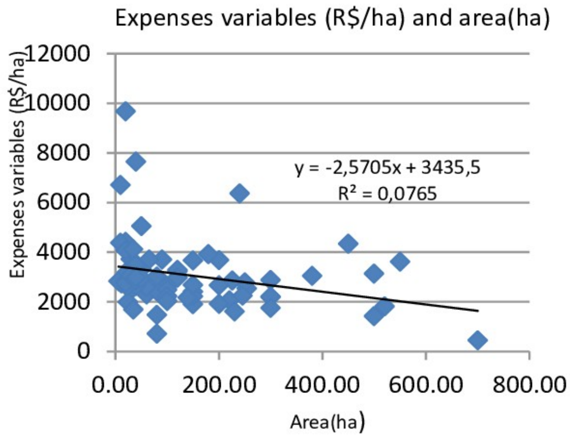

Fig. 3. Regression between area (ha) and variables expenses (R$/ha)

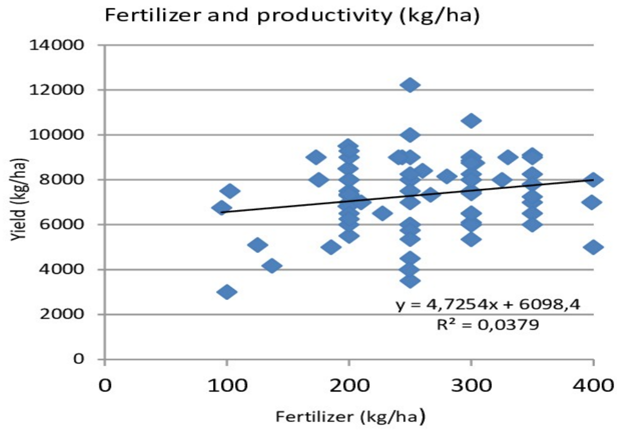

Fig. 4. Regression between fertilizer (kg/ha) and yield (kg/ha)

The area correlated significantly at the 5% level (Table 1) with the variable expenses per ha (R of -0.276), indicating that as the area increases, the variable expenses/ ha decreases (Fig. 3). This result is in agreement with the previous one of Fig.1, where larger areas present better economic results. Therefore, lower variable expense/ha as a function of larger areas is one of the causes of obtaining higher contribution margins as the planted area is get increased (Fig. 1).

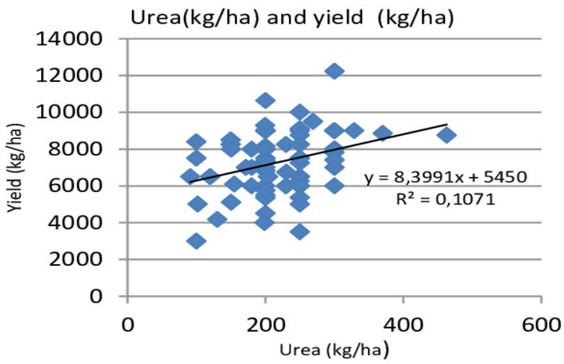

Fig.5. Regression between urea (kg/ha) and yield (kg/ha)

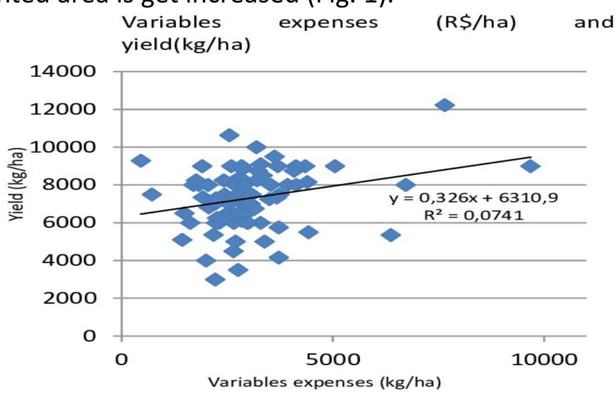

Fig.6. Regression between variables expenses (R$/ha) and yield (kg/ha)

Rice yield presented a significant correlation coefficient (R = 0.194 at 5% level) with the applied fertilizer (Table 1), indicating that yield increases with the increase of fertilizer applied per ha (Fig.4).

The same happened between productivity and kg of urea (R = 0.327), with a positive correlation at a 1% level (Table 1). Also demonstrating that yield increases in proportion to the amount of urea in the crop (Fig.5) as expected by SOSBAI (2018). In 2006, when the IRGA census was conducted (IRGA, 2006), an average of 179 kg of urea per hectare was used. In the present study, it was found that this amount increased, reaching an average of 222 kg/ha, around 50kg more of urea per ha. This increase, however, is not much, and higher productivity could be achieved with the use of higher amounts of urea (Fig.4). Thus, 300 kg could provide an average yield of around 8000 kg/ha, according to the regression obtained. This amount of 300 kg/ha of urea is higher than the current average recommendation of 110 kg/ha (SOSBAI, 2018) for high yields. However, it is in line with the recommendation of 140 to 150 kg/ha for very high yields (SOSBAI, 2018).

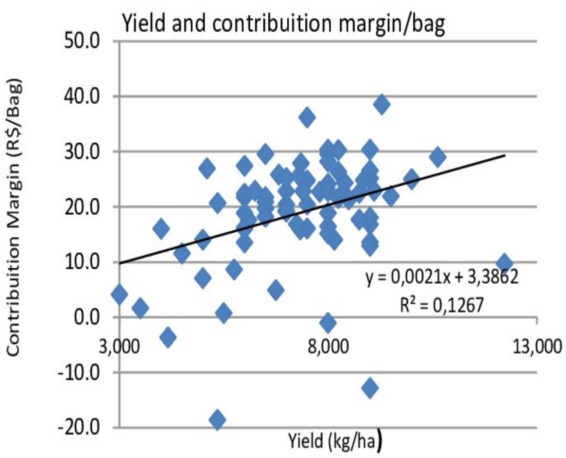

Fig. 7. Contribution margin/50 kg seed bag and yield (kg/ha)

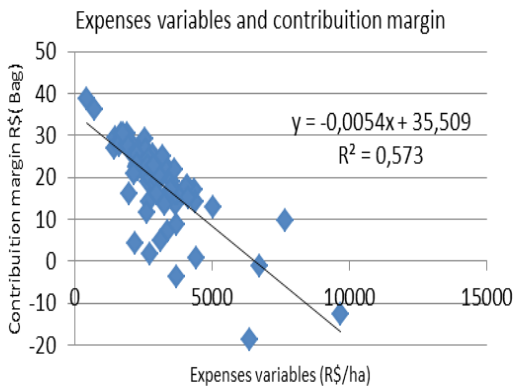

Fig. 8. Expenses variables (R$/ha) and contribution margin/bag

An increase in rice yield was associated with an increase in spent per hectare, shown by a significant correlation (R = 0.272) at a 5% level (Table 1), with a determination coefficient of 0.0741(Fig. 6), which means that by applying more capital to the crop, higher grain yields it will be obtained. This assumption will be expected with fertilizer and urea, as we already said previously that the application of modern inputs improves productivity and this entails higher expenses.

On the other hand, the contribution margin per bag correlated significantly (at a 1% level) with yield (R = 0.356), indicating that the higher the yield, the greater the contribution margin per bag (Fig.7). This result goes in line, as the contribution margin is the result of productivity (calculated as yield multiplied by the obtained prices) minus variable expenses.

The correlation (Table 1) between variable expenses and contribution margin per bag was significant at a 1% level (R = -0.756). Being a negative correlation, it indicates that as variable expenses increase, the contribution margin per bag decreases. Once again, considering the margin calculation form, this bottom line was expected (Fig.8).

Conclusion

Besides we found nine significant correlations, being five of them at probability level of 1%, the expenses variables against contribution margin/bag had the higher correlation level and also the upmost coefficient of determination, around 60%, which is meaningful at all.

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Economic result of rice crop in the 2019 grow season

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Introduction

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Our research aimed to evaluate the costs directly with the rice farmers, in a random sampling, and to calculate the monetary result of each field studied through the contribution margin index. Moreover, the objective was to obtain and analyses significant correlations between costs and production outcomes, aiming to reports the relationships we found.

Material and Methods

To collect data for this research, the IRGA census (IRGA, 2006) was initially used to obtain the farmers' contacts, selecting some at random to form a sample. Therefore, the relevant data of each selected rice farmer has been surveyed by phone calls. The information obtained was name of the property, acreage, land tenure, production, value of production and machinery, quantity of urea and other fertilizers, spent fuel, seeds, interest on loans, labor expenses, aviation expenses, fungicide, insecticide and herbicides, electricity, own or outsourced drying, freight, commission expenses, contracted machinery, insurance costs, storage, technical assistance, variables expenses and environmental taxes.

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Results

The average yield of rice for the State of Rio Grande do Sul in this season was 7.508 kg/ha, according to data from the Rio-grandense Rice Institute (Instituto Rio-grandense do Arroz - IRGA, 2019). In the present study, the yield was 7,315 kg/ha on average, which is very close to that estimated by IRGA. Probably this difference is due to the low participation, in our research, of rice farmers of the southern zone of the State, where the productivity was higher (8,198 kg/ha) in the growing season 2018/ 2019.

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*significant at 5% of probability
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The area correlated significantly, at a 5% level (Table 1), with the contribution margin per bag (R = 0.227), indicating that the bigger the area is, the higher the contribution margin per bag is. That means larger areas are related to better economic results.

Furthermore, the area had a significant correlation with the base fertilizer (at a 1% level), presenting a coefficient of correlation -0.34 (Table 1). This negative correlation indicates that larger areas use a lower amount of fertilizer per hectare, indicating that farmers with smaller areas use more fertilizer per hectare, thus performing a more intensive production with more costs.

The area correlated significantly at the 5% level (Table 1) with the variable expenses per ha (R of -0.276), indicating that as the area increases, the variable expenses/ha decreases. Therefore, lower variable expense/ha correlated with larger areas is one of the causes of obtaining higher contribution margins as the planted area has got increased.

Rice yield presented a significant correlation coefficient (R = 0.194 at 5% level) with the applied fertilizer (Table 1), indicating that yield increases with the increase of fertilizer applied per ha. The same happened between yield and kg of urea (R = 0.327), with a positive correlation at a 1% level (Table 1). Also demonstrating that yield increases with the amount of urea in the crop, as expected by SOSBAI (2018).

An increase in rice yield was associated with an increase in expenses per hectare, shown by a significant correlation (R = 0.272) at a 5% level (Table 1).

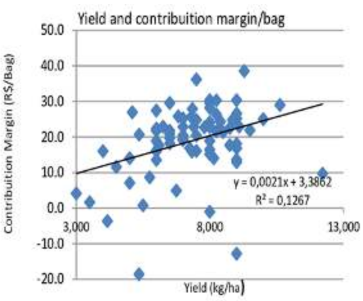

Fig. 1. Contribution margin/50 kg seed bag and yield (kg/ha)

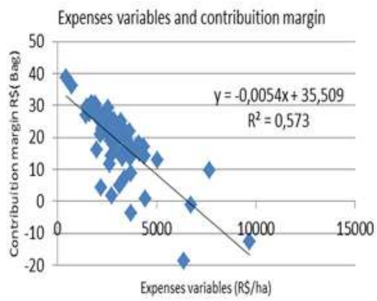

Fig. 2. Variable expenses(R$/ha) and contribution margin/bag

On the other hand, the contribution margin per bag correlated significantly (at a 1% level) with yield (R = 0.356), indicating that the higher the yield, the greater the contribution margin per bag (Fig. 1). This result goes in line, as the contribution margin is the result of productivity (calculated as yield multiplied by the obtained prices) minus variable expenses.

The correlation (Table 1) between variable expenses and contribution margin per bag was significant at a 1% level (R = -0.756). Being a negative correlation it indicates that as variable expenses increase, the contribution margin per bag decreases (Fig.2). Once again, considering the margin calculation form, this result was expected.

Conclusions

Although we found nine significant correlations, being five of them at a probability level of 1%, the expenses variables against contribution margin/bag had a higher correlation level, and also the maximum coefficient of determination, around 60%, which is meaningful at all.

Brazil Certificate - Rice export value added

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ABSTRACT

The rice produced in Rio Grande do Sul (RS) has quantity (productivity + technologie) that contributes to food security, quality (organoleptide + food safety + varietal identification) that contributes to value addition and positive image and meets safety, requirements environmental (environmental licensing + rural land register) that contribute to the preservation of the Pampa Biome. All these positive aspects are the basis for an official certification of the Brazilian government whose identification label is Brazil Certificate: Quality Agriculture. The rice industry in RS also has technology to focus the concept of quality with consumers and associate positive image, enabling innovation for a market that requires traceability and certification. The challenges faced by Brazilian rice exporters include overcoming phytosanitary and environmental barriers, consolidating sales to newly conquered markets and ensuring customer loyalty. In this context, an internationally recognized certification, such as the Brazil Certified: Quality Agriculture, which has National Institute of Metrology, Quality and Technology as the certifying agency provides confidence to the markets and, consequently, transparency for consumers. This Brazilian seal is required through the voluntary adoption of the Specific Technical Standard (NTE) for Integrated Rice Production (PIA), published in the Federal Official Gazette on November 14, 2016 (Normative Instruction N° 42, Ministry of Agriculture and Food Supply). For the producer, NTE Arroz represents the rationalization of the use of inputs; the reduction of production costs; the reduction of environmental risks and the responsible use of water and soil resources. The PIA is a modern system based on good farming practices that research institutions and Brazilian law advocate. The PIA encompasses technologies that prioritize natural regulatory mechanisms in Integrated Pest Management. In addition, technologies that are in line with the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Economy in Agriculture.

Key words: quality, security, *Oryza sativa* L., sustainable economy.

Brazil Certificate - Rice export value added

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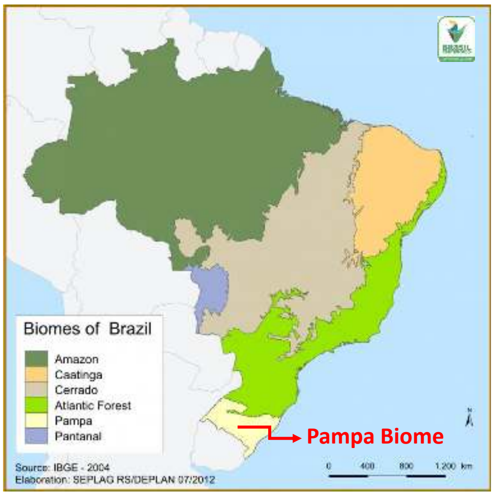
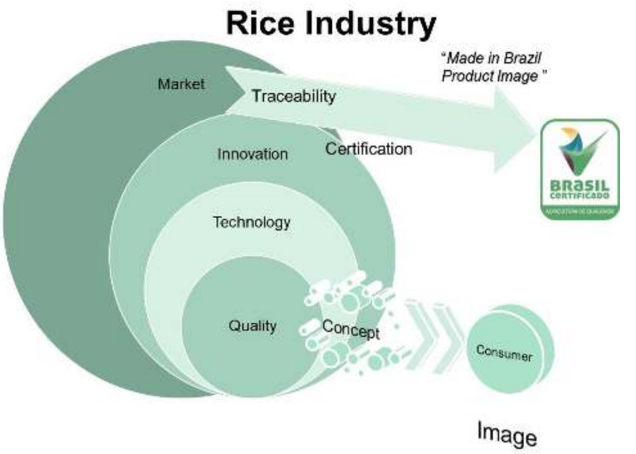
Introduction

The rice produced in Rio Grande do Sul (RS) has:

- quantity (productivity + technologie): that contributes to food security
- quality (organoleptide + food safety + varietal identification) that contributes to value addition and positive image and meets safety;
- requirements environmental (environmental licensing + rural land register) that contribute to the preservation of the Pampa Biome



- All these positive aspects are the basis for an official certification of the Brazilian government whose identification label is **BRAZIL CERTIFICATE: QUALITY AGRICULTURE**



Results

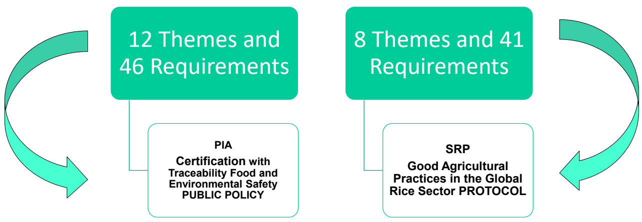
- The challenges faced by **Brazilian rice exporters** include overcoming phytosanitary and environmental barriers, consolidating sales to newly conquered markets and ensuring customer loyalty

Internationally recognized certification, such as the **BRAZIL CERTIFIED: QUALITY AGRICULTURE,** which has National Institute of Metrology, Quality and Technology as the certifying agency provides confidence to the markets and, consequently, transparency for consumers.

- Brazilian seal is required through the voluntary adoption of the
- Specific **Technical Standard (NTE) for Integrated Rice Production (PIA),** published in the Federal Official Gazette on November 14, 2016 (Normative Instruction Nº 42, Ministry of Agriculture and Food Supply);
- For the producer, NTE Arroz represents the rationalization of the use of inputs; the reduction of production costs; the reduction of environmental risks and the responsible use of water and soil resources.

TECHNICAL STANDARD FOR INTEGRATED RICE PRODUCTION

- Harmonization with the UN Sustainable Rice Platform (SRP) and Private Protocols (EurepGap / European Retailers / BPA)



Conclusions

- The PIA is a modern system based on good farming practices that research institutions and Brazilian law advocate;
- The PIA encompasses:

- technologies that prioritize natural regulatory mechanisms in Integrated Pest Management.
- technologies that are in line with the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Economy in Agriculture.

Evaluation of energy consumption in rice-based and alternative- cropping systems through process-analysis

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Key words: assessment, cropping system, engineering, indicator, sustainability

INTRODUCTION

Various aspects, like economic, environmental, social and agronomic, should be considered to evaluate the sustainability and performance of cropping systems. Whilst a comprehensive, multi-dimensional array is adequate for comparisons across distinct systems (Bimonte *et al*., 2016), an in-deep understanding of strengths and weaknesses of each cropping system – to identify options for smart interventions – requires a more detailed analysis of the system itself (Dejaco *et al*., 2017). Process-analysis (PA) is an exploration method based on the collection of information from each step that a production system is composed of. PA is commonly used to monitor and improve processes in commerce, construction and industries (e.g. Strobel *et al*., 2020), but the approach can also be adapted to evaluate agricultural cropping systems. The objective of this work was to quantify and compare the energy consumption of distinct lowland cropping systems using process-analysis.

MATERIAL AND METHODS

A study was conducted in the Lowlands Experimental Station from Embrapa, in Capão do Leão, RS, Brazil (-31.81 S; -52.47 W), where five cropping systems were evaluated during nine cropping seasons. The cropping systems were laid out in large-scale plots (from 3.1 to 11 ha), using similar machinery, inputs and agricultural procedures as in nearby commercial farms. All crops were dry-seeded, and rice was irrigated by continuous flooding, from V3 up to harvest. The five agricultural systems evaluated were:

a) Rice-Fallow; a cropping system comprising 3 years of dry-seeded, minimum-tillage irrigated rice, followed by 3 years of fallow (2 full cycles, in this specific case with 12 years of data). During fallow, cattle for meat production occupied the fields at a rate of 1.1 head ha^{-1};

b) Rice-rice-soybean-soybean rotation, with conventional soil tillage (Rice-Soybean CT). During each summer cropping season, one crop was cultivated;

c) Rice-rice-soybean-soybean rotation, with minimum soil tillage (Rice-Soybean MT). As in (b), during the summer cropping season just one crop was cultivated;

d) Rainfed crops integrated with beef-livestock, placed over large-based ridges (Ridges and Cattle). Soybean and maize were cultivated sequentially (one crop per summer season) in no-till, on permanent ridges (8 m wide and 0.4 m high in the center), constructed in mid-2006. In the winter seasons a pasture composed of Italian ryegrass (*Lolium multiflorum*) and black oats (*Avena sativa*) was cultivated, with beef-cattle placed at a stocking rate adjusted to a forage allowance of 12%.

e) Rainfed crops integrated with winter cover crops, placed over large-based ridges (Ridges and Cover Crops). The same as (d), except that during winter hairy vetch (*Vicia sativa*) and radish (*Raphanus sativus*) were also seeded to make up the pastures. In the last 2 years, beef cattle was placed at low density (forage allowance of 24%) on the winter cover crops.

Data was collected per cropping system and comprised all inputs used in the fields (fertilizers, seeds and pesticides), consumption of fuels, lubricants and electricity, machinery specifications, machinery operational time and labor time. All collected data was converted into a single unit of energy (MJ) to enable calculations related to energy demand. Each cropping system was analyzed by organizing the inputs according to input type (Table 1: fuels, fertilizers, seeds, pesticides, energy on machinery and human labor) and main agricultural processes (Table 2: soil preparation, seeding, plant nutrition, pest management, irrigation, harvest, cattle management and transports). Values represent the yearly averages of the energy consumed in each cropping system, for 12 (Rice-Fallow) or 9 (other systems) years of cultivation, ignoring the influence of individual crops and cropping seasons. A more detailed description about the methodology and the cropping systems can be assessed in Theisen, 2017.

RESULTS

Average total annual energy consumption per cropping system ranged from 15.2 to 20.7 GJ ha^{-1} per year. The lowest energy demand was observed for the Rice-Fallow system, while the highest consumption was found for the Rice-soybean rotation system managed in conventional soil tillage. This result was partially expected, since Rice-Fallow is a non-intensive model of production, with 3 years-fallow following 3-years of rice cultivation. At the same time, Rice-Soybean CT presented a high-energy demand, even though it does not belong to the most intensive cropping systems in this study (in both rice-soybean systems no cultivation occurred during winter). Compared to the other systems, the processes soil preparation and irrigation were important energy sinks for this cropping system, consuming 35% of the overall energy demand (7,657 MJ ha^{-1} per year). In the comparable Rice-Soybean MT, for instance, these two processes consumed just 27% of the energy, summing up to an equivalent of 5,917 MJ ha^{-1} per year. This difference between the two rice-soybean rotation systems was mainly due to the change in the way the soil was managed: from conventional to minimum till, represented a reduction of energy equivalent to almost 40 liters of diesel-fuel per hectare per year.

Plant nutrition was the most important consumer of energy. It embodied between a little less than one-third up to a half of all energy consumed by a cropping system. Both ridge-based cropping systems used up the most, corresponding to about 50% of their total energy consumption (Table 2). For this process the fertilizers, in particular nitrogen, was the most important driver: the N itself represented between 19% to 29% of all energy consumed by a cropping system (Table 1).

In cropping systems with irrigated rice in the rotation scheme, the process of irrigation was the second most important sink of energy, with a demand close to 22% (4.1 GJ ha^{-1} yr^{-1}) of all energy consumed. It is worth to note that these values are the average of a long-term essay: in cropping seasons cultivated with irrigated rice, energy demand on irrigation was almost twice the values presented.

The ‘seeding’ process also consumes a significant amount of energy, independent of the cropping system evaluated. This important agricultural process presented an average energy consumption of 20% of the total energy spent in the fields. For this process, the seeds represent the most important component. Energy represented by seeds varied from 5.5 to almost 10 times more than the fuels utilized to run the seeders. Seeds contain a high energetic profile, because of the elevated energetic cost required for its production (e.g. special care in the field, and additional steps like processing, treatments, packaging and transports).

The energy represented by pesticides, machinery and human labor was almost negligible when compared to the total amount of energy embedded by the other components utilized in the cropping systems. These three factors together made up, on average, just 7% of energy demanded, and a half of this value was represented by the energetic depreciation and energetic embodiment in the machinery. In the same way, some processes like transports and cattle management represented a rather limited energetic demand when compared to the other processes (Table 2).

The overall conclusion from this study is that the partitioning of cropping systems into logical steps is a convenient way to understand the energy demand of a production system and to compare it with alternative systems. For typical lowland production systems in which irrigated rice is part of the rotation scheme, irrigation is an important process, as well as are plant nutrition and seeding. In case of interventions to optimize these cropping systems, we believe this kind of information can help in decision making to prioritize the actions that will offer the best returns.

Table 1. Energy used (MJ ha^{-1} yr^{-1}) by type of input in five cropping systems established on an experimental station in the lowlands in south Brazil. Averaged values based on 12 (Rice-Fallow) and 9 (other systems) cropping seasons.

Input type	Cropping systems				
	Rice-Fallow	Rice-Soybean CT	Rice-Soybean MT	Ridges and Cattle	Ridges and Cover crops
	Energy demand (MJ ha^{-1} $year^{-1}$)				
Fuels (and electricity *)					
Irrigation (*)	3932	3812	3812	0	0
Soil preparation	1956	3207	1642	1125	817
Plant nutrition	424	622	655	960	956
Pest control	419	1116	1209	1360	1302
Seeding	224	357	375	673	532
Harvest	588	1175	1175	1493	1493
Transports/Cattle m.	236	174	166	259	176
Sub total	7779	10463	9034	5870	5276
Fertilizers					
N	3081	4258	4258	5463	5514
P	666	1340	1340	1352	1509
K	517	1155	1155	1461	1349
Sub total	4264	6753	6753	8276	8372
Seeds	2090	3423	3403	3705	3899
Pesticides					
Herbicides	233	262	513	592	696
Insecticides	2.4	28	29	56	60
Fungicides	20	36	36	22	22
Adjuvants	37	57	73	48	59
Sub total	292	383	651	718	837
Machinery					
Irrigation	230	223	223	0	0
Soil preparation	191	299	142	100	78
Plant nutrition	58	86	98	122	124
Pest control	45	86	91	143	138
Seeding	36	55	67	105	87
Harvest	55	109	109	134	134
Sub total	615	858	730	604	561
Labour					
Irrigation	91	88	88	0	0
Soil preparation	10	18	9.9	5.4	4.1
Plant nutrition	4.5	6.7	6.5	9.7	8
Pest control	3.6	9.6	10	12	11
Seeding	1.9	3.5	3.6	5.3	4.7
Harvest	1.8	4	4	4.4	4.4
Transports and Cattle m.	5.2	1.3	1.2	5.7	2.5
Sub total	88	102.1	94.2	42.5	34.7
Total# (MJ ha^{-1} yr^{-1})	15158 (4003)	22011 (2605)	20694 (2496)	19216 (1365)	18980 (1815)

* Electricity used for pumping in irrigated rice paddies was converted to fuel-equivalent energy units.
# Values between parentheses are the SEM. N=12 (Rice-Fallow); N=9 (other cropping systems).

Table 2. Energy used (GJ ha^{-1} yr^{-1}) per agricultural process in five cropping systems established on an experimental station in the lowlands in south Brazil. Averaged values based on 12 (Rice-Fallow) and 9 (other systems) cropping seasons.

Agricultural process	Cropping systems				
	Rice-Fallow	Rice-Soybean CT	Rice-Soybean MT	Ridges and Cattle	Ridges and Cover crops
	Energy demand (GJ ha^{-1} $year^{-1}$)				
Soil preparation	2.16	3.52	1.79	1.23	0.90
Seeding	2.35	3.84	3.85	4.49	4.52
Plant nutrition	4.75	7.47	7.51	9.37	9.46
Pest management	0.78	1.62	2.01	2.29	2.35
Irrigation	4.22	4.09	4.09	0	0
Harvest	0.64	1.29	1.29	1.63	1.63
Cattle management	0.12	0	0	0.15	0.08
Transports	0.12	0.17	0.17	0.11	0.10

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8 Rice irrigation and soils

Irrigation management and variety effects on rice grain Arsenic levels in Uruguay.

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ABSTRACT

Rice is the most important staple component of the human diet worldwide. The higher amounts of arsenic accumulation in its grain in relation to other crops, determines a potential toxicity risk to humans. This research project aimed to determine the inorganic arsenic accumulation in rice grain (iAs) in two contrasting soil sites in Uruguay, Paso Farias-Artigas (PF) and Paso de la Laguna-Treinta y Tres (PdL), with two different mitigation practices. These being firstly irrigation management techniques and secondly the use of different varieties. Five experiments were conducted with a split plot design with four blocks over three rice growing seasons from 2014 until 2017. The experimental sites included two irrigation treatments: continuous flooded (C) and alternate wetting and drying (AWD). In treatment C, flooding started 15 days after emergence and maintained throughout all the crop cycle with a water layer of 10 cm. The AWD treatment allowed the soil to dry periodically (water depletion of 50% of soil available water) until panicle initiation. After this period, it was managed as C. The split plots included different varieties: Indicas and Japonicas. The Indica varieties planted were: INIA Merín, INIA Olimar, El Paso 144 and the Japonicas were: INIA Parao, INIA Tacuarí (3 Indicas +1 Japonica in PF site and 2 Indicas + 2 Japonicas in PdL site). Average iAs accumulated in rice grain were 0.07 mg kg^{-1}, well below international limits, even under the C irrigation technique. The iAs levels registered in PdL were significantly higher in relation to PF site. It was found that iAs accumulation in rice grain can be further reduced by the implementation of AWD in certain soil types (PF). However, AWD determined a significant reduction in rice grain yield. *Japonica* varieties had a lower accumulation of iAs in rice grain, in comparison with *Indicas* at both sites.

Key words: Irrigation, Arsenic, AWD, Rice.

Irrigation management and variety effects on rice grain Arsenic levels in Uruguay

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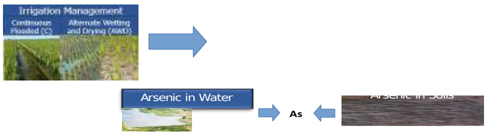
Introduction

Rice is the most important staple component of the human diet worldwide. The higher amounts of arsenic accumulation in its grain in relation to other crops, determines a potential toxicity risk to humans. The rice sector is facing the challenge of achieving high yields to meet the increasing global food demand while maintaining food safety.



Objective

This research project aimed to determine the inorganic arsenic (iAs) accumulation in rice grain in two contrasting soils sites commonly used for rice production in Uruguay. Another objective was to identify alternative irrigation management techniques to traditional flooding that could be used to limit or reduce the iAs accumulation in grain and to determine differences in iAs levels within the most commonly planted rice varieties in Uruguay.

Material and Methods

Experiments (5) were conducted in 2 experimental units (PF and PdL) over 3 rice growing seasons (October to March) from 2014 until 2017. Experimental design was a split plot with 4 blocks, including two irrigation treatments: continuous flooded (C) and alternate wetting and drying (AWD) and 4 varieties (Figure 1). In treatment C, flooding started 15 days after emergence and maintained throughout all the crop cycle with a water layer of 10 cm. The AWD treatment allowed the soil to dry periodically (water depletion of 50% of soil available water) until panicle initiation. After this period, it was managed as C. The split plots included different varieties: Indicas (INIA Merín, INIA Olimar, El Paso 144) and Japonicas (INIA Parao, INIA Tacuarí). Statistical analyses were all performed in R software using the emmeans and nlme packages (R Core Team, 2018).

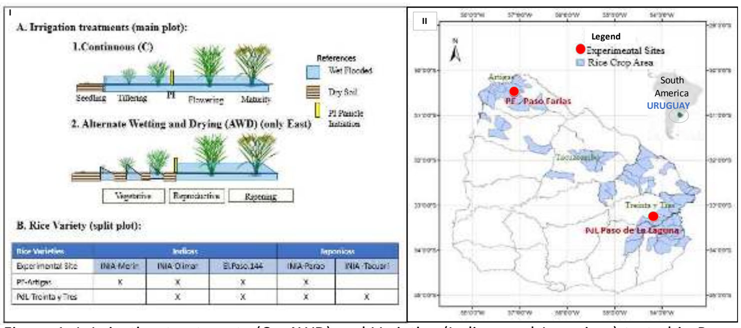


Figure 1. I. Irrigation treatments (C - AWD) and Varieties (Indicas and Japonicas) tested in Paso Farias (PF) North and Paso de la Laguna (PdL) East. II. Location of the two experimental sites in Uruguay.

Results

Arsenic levels registered in Irrigation water and soils were found to be very low, which resulted in low levels of iAs accumulated in rice grain at both sites. Total As in soils were well below the Canadian limit for agricultural soils of 12 mg kg^{-1} (CCME) and As in water were below the limited restriction values for irrigation surface water of 0.05 mg L^{-1} (Class 2a) and 0.005 mg L^{-1} (Class3) (Decreto N° 253/79, 1979).

Table 1. Arsenic in soils, water and iAs levels accumulated in polished rice grain by site.

Classification criteria	Arsenic in Soils at sowing		Arsenic in water	Inorganic Arsenic in Grain
	Total Arsenic (tAs mg kg^{-1})	Bioavailable Arsenic (bioAs µg L^{-1})	(As mg L^{-1})	(iAs mg kg^{-1})
Site				
PdL	3.62 a	30.30 a	0.00272 a	0.091 a
PF	2.14 b	15.21 b	0.00176 b	0.043 b
Average	*2.88*	*22.76*	*0.00224*	*0.067*
CV%	*27.56*	*15.4*	*22.72*	*4.524*
P<0.05	***	***	***	***

Means followed by different letters are significantly different with a probability less than 5% (P < 0.05). Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05; NS: non-significant differences. CV: coefficient of variation.

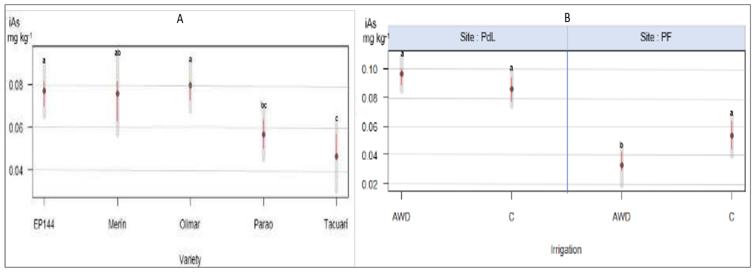
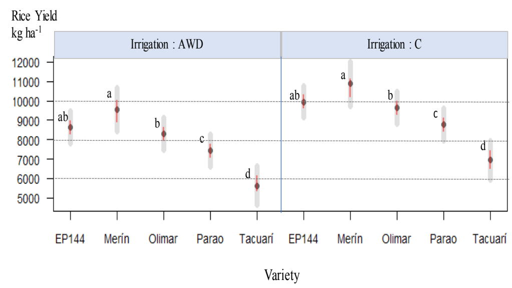


Figure 2. Inorganic arsenic accumulated in polished rice grain for: A. Varieties and B. Irrigation management by site. Black dots represent means, red lines indicate confidence interval by Tukey. Different letters indicate significant differences within treatments with a probability less than 5%.

AWD irrigation treatment resulted in a significant yield reduction of 14% in relation to C. Japonica cultivars registered the lowest rice grain yields.

Figure 3. Rice grain yield (kg ha^{-1}, 14% moisture) for different varieties by irrigation techniques. Black dots represent means (least square means), red lines indicate confidence interval by Tukey. Different letters are significantly different with a probability less than 5%.



Conclusions

Inorganic Arsenic levels (iAs) accumulated in polished rice grain grown in Uruguay (average 0.07 mg kg^{-1}) were found to be well below the limit proposed by the CODEX international standards of 0.20 mg.kg^{-1} (FAO and WHO, 2019), even under the traditional continuous irrigation technique.

The implementation of AWD in certain soil types can further reduce the iAs accumulation in rice grain.

Japonica varieties had a lower accumulation of iAs in rice grain, in comparison with *Indicas* at both sites.

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Irrigation management strategies to increase water productivity in *Oryza sativa* (rice) in Uruguay

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ABSTRACT

Traditional rice irrigation systems in Uruguay are fully irrigated and early continuously flooded irrigation accounts for a high volume of water used. The purpose of this study was to determine irrigation techniques that increase water productivity (WP) allowing a reduction in water input without negatively affecting grain yield in Uruguay. Ten experiments were conducted over a six-year period from 2009 to 2015, in three experimental units located among the major rice growing regions. Treatments included: early continuous flooding (C), alternate wetting and drying (AWD), intermittent flooding until panicle initiation (IP) and intermittent flooding during all crop growth period (I). All treatments were planted on dry soil. In treatment C flooding started 15-20 days after emergence and a water layer of 10 cm above the soil surface was maintained throughout all the crop cycle. In treatments IP and I, the water level alternated between 10 cm and 0 cm and was re-established when the soil was still saturated. The AWD treatment alternated saturated and unsaturated soil conditions until panicle initiation. IP and I over three seasons led to significant savings in irrigation water inputs in the North and Central regions (averaged 35% or - 3986 m^3 ha^{-1}) in relation to C. In the East region, AWD allowed for a 29% (-2067 m^3 ha^{-1}) water saving in relation to the control but determined a significant yield loss of 1339 kg rice ha^{-1} (15% reduction) in relation to C. WP was increased by 23% in IP and 62% in I, in relation to the control C. Whole grain percentage was significantly reduced with I in the North region. Techniques that maintained the soil water at saturated conditions like intermittent flooding, allowed a reduction of water input with no significant effects on grain yield, which led to a significant increase in WP.

Key words: Rice, Irrigation, AWD, Water productivity

Irrigation management strategies to increase water productivity in *Oryza sativa* (rice) in Uruguay

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Introduction

The rice sector is facing great challenges in the coming years of not only achieving high yields to meet global food demand but also to use less water, energy, and other inputs per unit of production. Rice farming systems in Uruguay are fully irrigated and continuous flooded. New irrigation techniques need to be developed to use less water, minimize off-site impacts while preserving grain yield, quality and food safety.
Increases in water productivity would allow rice production to expand and/or allows the allocation of water to irrigate other crops or other users such as urban and industrial. In addition, increases in water productivity will also contribute to reduce pumping costs, improving the economic results and sustainability of the rice farming sector.

Objective

The main objective of this study was to determine irrigation techniques that increase irrigation water productivity (WPi) allowing a reduction in water input without negatively affecting grain yield in Uruguay.

Material and Methods

Experiments (10) were conducted from 2009 to 2015 (October-March), in three experimental units located among the major rice growing regions. Treatments included: early continuous flooding (C), alternate wetting and drying (AWD), intermittent flooding until panicle initiation (IP) and intermittent flooding during all crop growth period (I). Statistical analyses were performed using the packages lme4 and emmeans in R software (http://www.R-project. org/).

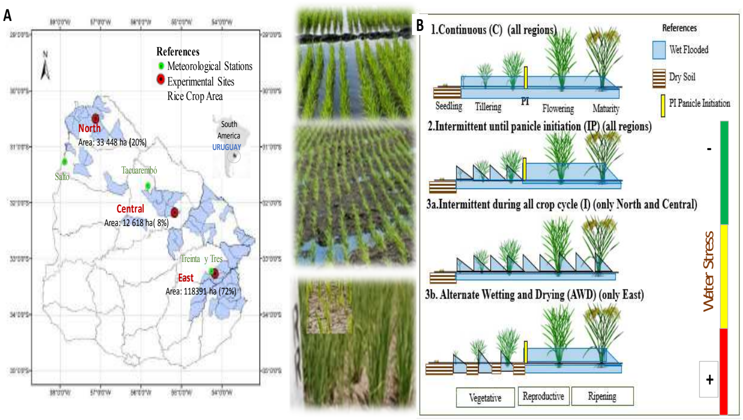

Figure 1. A. Experimental sites location and B. Irrigation treatments tested in different regions

All treatments were planted on dry soil. In treatment C, flooding started 15-20 days after emergence and a water layer of 10 cm above the soil surface was maintained throughout all the crop cycle. In treatments IP and I, the water level alternated between 10 cm and 0 cm and was re-established when the soil was still saturated. The AWD treatment allowed the soil to dry periodically (water depletion of 50% of soil available water) until panicle initiation. After this period, the field was continuously flooded as the control treatment.

Results

Alternative irrigation techniques like IP and I led to significant savings in irrigation water inputs in the North and Central regions (averaged 35% or -3986 m³ ha^{-1}) in relation to C. In the East region, AWD allowed for a 29% (-2067 m³ ha^{-1}) water saving in relation to the control but resulted in a significant yield loss of 1339 kg rice ha^{-1} (15% reduction) in relation to C. WPi was increased by 0.25 kg m-3 in IP and 0.68 kg m-3 in I, in relation to the control C. Traditional continuous flooding C is the most common irrigation technique in Uruguay and always registered the highest yields.
The whole grain percentage was significantly reduced with I in the North region in relation to C.

Figure 2. A. Irrigation water input m³ ha^{-1} (WI), B. Water productivity (kg m^{-3}) considering only irrigation water input, C. Rice Yield at 14 % moisture (kg grain ha^{-1}), D. Whole grain (%), for different treatments and rice regions in Uruguay. Black dot represents estimated marginal means, red arrow lines indicates confidence interval by Tukey. Different letters are significantly different with a probability less than 5%.

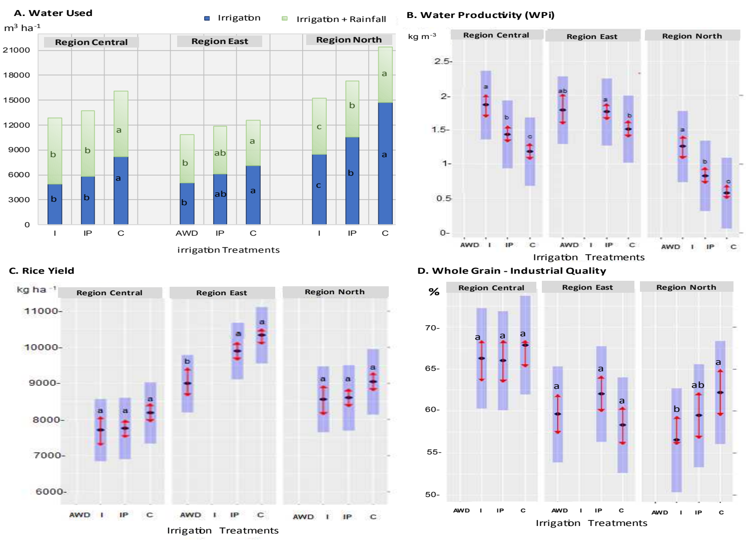

Table 1. Rice grain yield (kg ha^{-1}, 14% moisture) and Water Productivity, kg rice grain per m³ of water (kg m^{-3}) by irrigation treatments and regions.

Treatments	Rice Yield (kg ha^{-1})	Water Productivity (WP) kg m^{-3}	
		WPi-Irrigation	WPir-Irrigation + Rainfall
Irrigation			
1.Continuous (C)	9194 a	1.09 c	0.59 b
2. Intermittent until panicle initiation (IP)	8755 a	1.34 b	0.64 ab
3. Intermittent during all crop cycle (I)	8710 ab	1.77 a	0.71 a
4. Alternate Wettig and Drying (AWD)	7855 b	1.37 abc	0.62 ab
Average	*8628*	*1.39*	*0.64*
CV%	*3.75*	*14.49*	*5.75*
P<0.05	***	***	***
Region			
I. Central - Ce	7628 b	1.49 a	0.55 b
II. North - N	8485 b	0.88 b	0.48 b
III.East - E	9772 a	1.81 a	0.89 a
Average	8628	1.35	0.62
CV%	*4.3*	*15.71*	*6.34*
P<0.05	***	***	***
Irrigation*Region P<0.05	*NS*	*NS*	*NS*
Irrigation*Season - P<0.05	*NS*	*NS*	*NS*

Means followed by different letters are significantly different with a probability less than 5% (P < 0.05). Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05; NS: non-significant differences. CV: coeffiient of variation.

Conclusions

This study identified irrigation techniques that increased water productivity, across a range of irrigated rice growing environments in Uruguay.

Techniques that maintained the soil at saturated water conditions like intermittent flooding, allowed a reduction of water input with no significant effects on grain yield, which led to a significant increase in water productivity in relation to the control continuous flooded treatment.

Alternate Wetting and Drying (AWD) techniques allowed soil moisture to drop below saturation and yield was found to be affected negatively.

Comparison of delayed flood and furrow irrigated drill-seeded rice in south Louisiana

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ABSTRACT

Delayed flood is a major water management practice for rice production in south Louisiana, where the permanent flood is established at the 4-to 5-leaf growth stage or approximately 4 to 5 weeks after planting. Recently, furrow irrigated rice acreage has increased in Louisiana and could be a potential alternative rice production system for reducing water use in the future. However, yield loss from this practice is still uncertain. The objective of this study was to compare delayed flood and furrow irrigated drill-seeded rice production systems on grain yield and water use efficiency. Field experiments were conducted at the Louisiana State University Agricultural Center H. Rouse Caffey Rice Research Station near Crowley, Louisiana. Seeds of the hybrid rice cultivar CLXL745 were drilled with 20.3-cm row spacing on flat ground for delayed flood plots and on 70-cm wide raised beds with 20.3-cm row spacing for the furrow irrigation system. A single preflood nitrogen fertilizer (urea) was applied at the rate of 0, 100, 135, 168, 202, and 235 kg N/ha at the 4- to 5-leaf growth stage. Other field management practices were done in the same manner for both water management systems. Results indicated that the amount of water used was significantly lower in the furrow irrigation system as compared to delayed flood. However, yield reduction was observed in furrow irrigation by 22-30% varying by nitrogen application rates.

Key words: delayed flood, furrow irrigation, water use efficiency

Comparison of delayed flood and furrow-irrigated drill-seeded rice in south Louisiana

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Introduction

Traditional rice cultivation requires a sustained water supply during the production cycle. Earlier research findings tended to emphasize that rice grain yield was highly related to the amount of water used. The rice plant is most sensitive to water stress during the reproductive stage, when lack of water causes a high percentage of sterility. Water deficiency during the vegetative stages reduces plant height, tiller number, and leaf area and can sharply reduce yields if the water deficiency is not corrected and plants are unable to recover before flowering. In addition, the duration of moisture stress is more important than the growth stage at which the stress occurs. Intermittent drying or maintaining soil at continual saturation during the growing season considerably decreases rice yields in most environments.

Drill-seeded with delayed flood management is the dominant rice production system in Louisiana. Recently, furrow-irrigated rice acreage has increased in Louisiana and could be a potential alternative rice production system for reducing water use in the future.

Objective

To compare delayed flood and furrow-irrigated drill-seeded rice production systems on yield and water use efficiency (kg/m^3).

Material and Methods

- The experiments were conducted at the H. Rouse Caffey Rice Research Station, Louisiana State University Agricultural Center, near Crowley, Louisiana.
- Land preparation: Spring stale seedbed, Crowley silt loam soil.
- Two parallel experiments were set up with a RCBD, 6 treatments of nitrogen fertilizer rates, and 4 replications.

Fig 1. Drill seeded on flat ground for delayed flood.

Fig 2. Land preparation for drill seeding on furrows.

- Seeds of hybrid rice cultivar CLXL745 were drilled on Spring stale seedbed at the density of 108 seeds/m^2. The row spacing was 20.3 cm with the plot size of 7 rows x 4.88 m long.
- Fertilizer application:
  - At planting 0-24-24-2.7(Zn) at 113 kg/ha.
  - N fertilizer in the form of urea was applied 1 day before flooding for delayed flood, and 1 day before 1st furrow irrigation started. Variation rates of N associated with the treatments: 0, 100, 135, 168, 202, and 235 kg N/ha.
- Water management for each trial:
  - Delayed flood (permanent flood was applied at 4- to 5-leaf stage and drained at 2 weeks before harvesting.
  - Furrow-irrigated (water was applied using polypipe when needed, no flooded water retained on the soil surface)
- Grain yield from the entire plot was adjusted to 12% moisture.

Results

Fig 3. Drill seeded on seedbed for furrow-irrigated.

Fig 4. Irrigation water run through polypipe from the lower elevation side.

Fig 5. Flood water was applied at 4- to 5-leaf stage until 2 weeks before harvest in delayed-flood.

Fig 6. Irrigation applied when needed for furrow-irrigated.

- Rice maturity in furrow-irrigated system was faster than delayed flood system (Table 1)
- Plant heights in delayed flood were taller than in furrow-irrigated system
- Grain yield in furrow-irrigated were lower than delayed flood by 22-30% depending on N rate
- Furrow-irrigated system reduced irrigation water by 53% and total water (included rainfall) by 5%
- Water use efficiency was lower in furrow-irrigated (1.25 kg/m^3) compared to delayed flood (1.62 kg/m^3)

Table 1. Comparison of agronomic data and yield between delayed flood and furrow-irrigated systems.

N Rate (kg N/ha)	(day)		Plant Height (cm)		Yield (12% M) (kg/ha)	
	Delayed	Furrow	Delayed	Furrow	Delayed	Furrow
0	95.5	81.5	81.3	73.7	5,963	4,642
100	98.3	82.5	102.9	88.4	12,189	8,830
135	99.0	82.5	106.2	87.6	12,581	8,745
168	99.8	82.5	109.2	90.9	12,246	9,289
202	99.5	82.8	112.5	90.9	12,878	9,476
235	100.0	83.0	108.0	90.2	12,809	9,003
LSD P = 0.05	1.0	0.71	3.67	3.26	1005.3	837.2
C.V. (%)	0.7	0.57	9.32	8.28	5.83	6.67
Prob (F)	0.0001	0.0085	0.0001	0.0035	0.0001	0.0001

Conclusions

A furrow-irrigated system can reduce water use as compared to a delayed flood system. However, significant yield reduction was observed. Therefore, a furrow-irrigated system would be beneficial in a growing area that has limited water.

Acknowledgements

This project was supported by the Louisiana Rice Research Board.

Rice-Soybean-Pasture/Cattle rotation under pivot irrigation, new horizons for Uruguayan agriculture

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ABSTRACT

Sprinkler irrigation with pivot has been largely used around the World for different dryland crops and pastures. More recently, rice has also been tried looking for water use efficiency, novel crop rotations and reduced costs. EMBRAPA Clima Temperado conducted several research projects on this matter, and farmers are increasingly using pivots for rice production in Rio Grande do Sul. This project intends to validate this technology in Uruguay, installing a 20 ha-pivot in a farm near the city of Vergara, where a rice–winter grass–soybean rotation is being installed. The main goal is to demonstrate to farmers the feasibility of a lucrative and sustainable production system with rice at its center, in which their income is improved and stabilized by high yield/low cost crops, and product diversification. Additionally, scientific bibliography points out improved environmental sustainability of this system with higher water use efficiency, reduced GHG emissions, and almost no arsenic in grain. All crops will be irrigated as needed and pastures will be grassed by calves for beef production. Yields, technical coefficients, management tips, costs, industrial quality and food safety parameters and economic results will be the output of this two-year project that starts in 2019-2020 season. The project is run by an alliance of innovation between GND - ARAMIS, INIA Uruguay and EMBRAPA Brazil and is partially funded by ANII (National Agency for Research and Innovation – Uruguay)

Key words: rice, pivot irrigation, crop rotations, water use efficiency, sustainability

Rice-Soybean-Pasture/Cattle rotation under pivot irrigation, new horizons for Uruguayan agriculture

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Introduction

Sprinkler irrigation with pivot has been largely used around the World for different dryland crops and pastures. More recently, rice has also been tried looking for water use efficiency, novel crop rotations and reduced costs. EMBRAPA Clima Temperado conducted several research projects on this matter (Scivittaro et al., 2017), and farmers are increasingly using pivots for rice production in Rio Grande do Sul. This technology approach has not been tried in Uruguay up to now.

Objective

This project intends to validate this technology in Uruguay. The main goal is to demonstrate to farmers the feasibility of a lucrative and sustainable production system with rice at its center, in which their income is improved and stabilized by other high yield crops, and product diversification. Additionally, scientific bibliography points out improved environmental sustainability of this system with higher water use efficiency, reduced GHG emissions, and almost no arsenic in grain..

Material and Methods

A 20 ha-pivot was installed in a farm near the city of Vergara in Treinta y Tres -Uruguay, where a rice–winter grass–soybean rotation started in the spring of 2019. All crops will be irrigated as needed and pastures will be grassed by calves for beef production.

To take the most for a two-year project, the irrigation circle is divided by halves and the rotation will run in each side with different crops. For 2019-2020 season one half is planted with rice and the other with soybean. Winter grasses will be seeded in both halves, and crops will change side for 2020-2021 season.

CROP MANAGEMENT TIPS	RICE	SOYBEAN
SOIL PH ADJUSTMENT	2400 KG/HA - CALCIUM CARBONATE	
PLANTING DATE	11.10.19	21.11.19
VARIETIES	INIA MERÍN/INIA OLIMAR	DM50i17
SEED DENSITY	130 KG/HA	80 KG/HA
PLANT POPULATION	110 PLANTS/M²	33 PLANTS/M²
BASAL FERTILIZATION NPK	21-92-35 KG/HA	0-70-110 KG/HA
TILLERING FERTILIZATION NPK	46-0-75 KG/HA	
COMPLEMENTARY FERTILIZATION	50-0-0 KG/HA	
RAINS FROM PLANTING TO 27.1.20	558 MM	135 MM
RAINS FROM BEGINING IRRIGATION	220 MM	135 MM
WATER IRRIGATION TO 27.1.20	494 MM	122 MM

Results and Conclusions

Yields, technical coefficients, management tips, costs, industrial quality, food safety parameters and economic results will be the output of this two-year project that covers 2019-2020 and 2020-2021 seasons.

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Arsenic content and speciation in Uruguayan Rice

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ABSTRACT

Rice is the most important cereal for human feeding. Rice production is essential to provide food security for many developing countries all over the world. Arsenic is a carcinogen class I element, being inorganic forms more dangerous to human health than organic ones. It can be present in soils by natural geogenic and anthropogenic sources. Arsenic absorption by rice plants is favored by flooding conditions. Main arsenic exposure paths to humans are through contaminated water and rice consumption. Maximum levels of inorganic and total arsenic have been set by different organizations involved in rice world commerce. World Health Organization (WHO) proposed a maximum level of inorganic Arsenic (iAs) of 0,20 mg/kg for polished rice. Mercosur limit for total arsenic (tAs) in grain has been set in 0,30 mg/kg in polished grain. FDA has set inorganic arsenic level in rice for baby food purposes in 0,10 mg/kg.

As a part of an overall multi institutional project seeking to determine the levels of this element and study potential genetic and management alternatives a country sampling strategy was developed. In two cropping seasons (2017-2018 and 2018-2019) 75 commercial rice samples were taken each year, totalizing 150 samples. These samples were taken all over Uruguayan rice production regions, including all main varieties and regions planted in the country. tAs and iAs where analyzed on polished rice samples.

Previously to this effort, several experimental plot studies where carried out in different locations where rice polished samples were also analyzed for tAs and iAs levels. By integrating all samples, a data base of 254 rice samples was generated. Average tAs and iAs levels where 0,21 and 0,06 mg/kg respectively. 78% percent of the samples analyzed for tAs where below the 0,30 mg/kg maximum level established in the Mercosur countries and 100% of the samples presented levels of iAs levels below the 0,20 mg/kg established by WHO and 88% where even below 0,10 mg/kg of iAs required for baby foods.

Key words: Rice, Arsenic, Oryza Sativa, Food safety; Uruguay

Arsenic content and speciation in Uruguayan Rice

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Introduction

Rice is the most important cereal for human feeding. Rice production is essential to provide food security for many developing countries all over the world. Arsenic (As) is a carcinogen class I element, being inorganic forms more dangerous to human health than organic ones. It can be present in soils by natural geogenic and anthropogenic sources mainly as arsenite – As^{3+} and arsenate – As^{5+}, and organic forms as dimethylarsinic acid (DMA) and methylarsonic acid.

Arsenic absorption by rice plants is favored by flooding conditions. Main arsenic exposure paths to humans are through contaminated water and rice consumption. Maximum levels of inorganic and total arsenic have been set by different organizations involved in rice world commerce (Table 1). As a part of an overall multi institutional project seeking to determine the levels of this element and study potential genetic and management alternatives a country sampling strategy was developed.

Table 1. Total (tAs) and inorganic arsenic (iAs) limits

Maximum level	Rice milling process	iAs (mg/Kg)	tAs (mg/Kg)
CODEX Alimentarious	Polished	0,20	
CODEX Alimentarious	Husked	0,35	
FDA (USA)	Rice based food	0,10	
MERCOSUR	Polished or Husked		0,3
IRAN (Gharachorloo et al.,2019)	Polished		0,15

Objective

The main objective of this sampling based-study is to know the actual situation of arsenic grain content in Uruguayan rice.

Another objective is to analyze spatial patterns and major factors (variety, soil type, water source, phosphorus levels, previous crop and crop management) affecting arsenic content in grain.

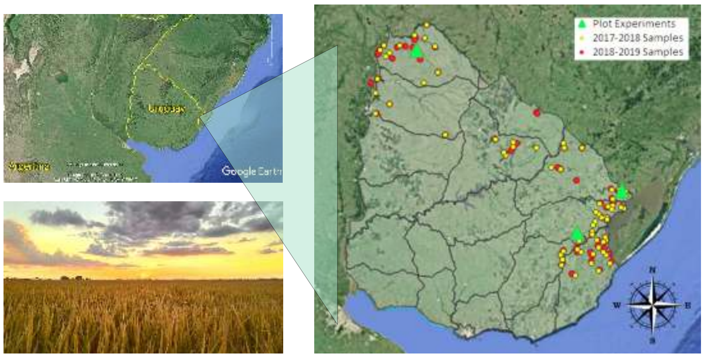
Material and Methods

Samples (total=150) were annually taken during two rice growing season (2017-18 and 2018-19, October-March), in all rice regions of Uruguay, including all main varieties. Samples were taken according to the proportion of planting area of each variety on each region (East, Center and North region).

Previously to this effort, several plot studies were carried out in different locations were polished rice samples were also analyzed for tAs (total arsenic) and iAs (inorganic arsenic) levels. In the cropping seasons 2014-2015, 2015-2016 and 2016-2017, five experiments were carried out, in two regions each year, less season 2015-2016 when just one experiment was carried out in the East region of Uruguay . Each experiment included all main varieties planted in Uruguay and two contrasting regions (East and North region). In addition, in the cropping season 2017-2018, a silicon and phosphorus fertilization experiment was carried in Rio Branco (East region), including 9 fertilization treatments in an Indica variety (Merin).

A data base of 254 rice samples in total was created by integrating all the samples mentioned above

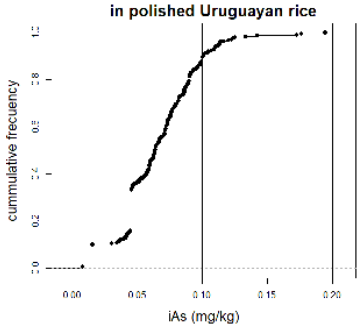
Map 1. Sample's and plot experiments locations



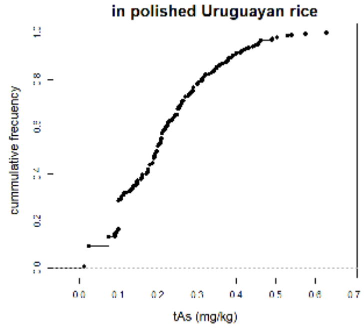
Results

Average tAs and iAs levels where 0,21 and 0,06 mg/kg respectively. 78% percent of the samples analyzed for tAs where below the 0,30 mg/kg maximum level established in the MERCOSUR countries and 100% of the samples presented levels of iAs levels below the 0,20 mg/kg established by CODEX Alimentarius and 88% where even below 0,10 mg/kg of iAs required for baby foods. (MERCOSUR, 2011; FAO and WHO, 2019; FDA, 2016).

Cumulative distribution of iAs concentration in polished Uruguayan rice



Cumulative distribution of tAs concentration in polished Uruguayan rice



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